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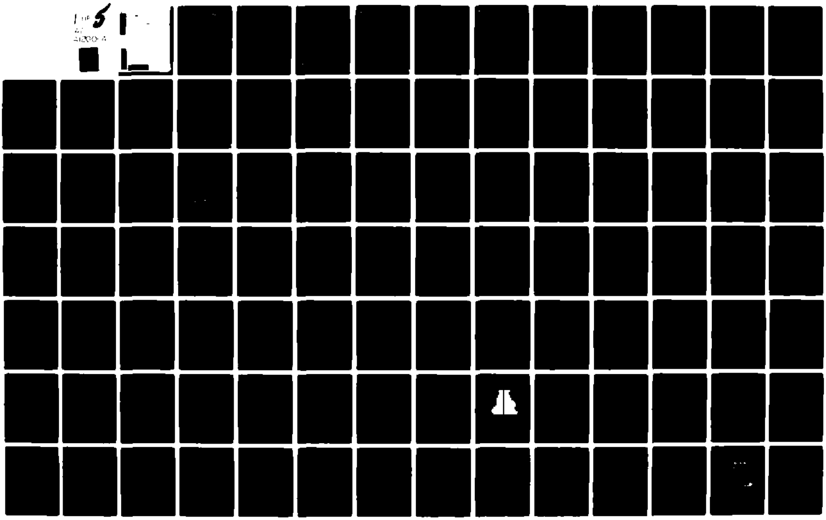

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The eight appendices to the main report provides descriptive material about the Blackstone River Basin. Appendices included in this volume are: problem identification, plan formulation, public views and responses, design and cost estimates, recreation and natural resources, social and cultural resources, economics, and hydrologic analysis.

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PAWCATUCK RIVER AND NARRAGANSETT BAY DRAINAGE BASINS
WATER AND RELATED LAND RESOURCES STUDY

BLACKSTONE RIVER WATERSHED

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Department of the Army
New England Division, Corps of Engineers
Waltham, Massachusetts
August 1981

APPENDIX 1

PROBLEM IDENTIFICATION

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INTRODUCTION

This Appendix provides descriptive material about the Blackstone River Basin and will serve as a background for later presentation of flood management problems.

The Blackstone River Basin constitutes the major portion of the Providence River watershed, one of the five segments forming the Pawtucatuck River - Narragansett Bay Drainage Basins (PNB) Study area which lies within southeastern Massachusetts, most of Rhode Island, and extreme southeastern Connecticut. The Blackstone River study area includes all of the Blackstone River tributaries in the vicinity of Worcester, Massachusetts to the estuary at Pawtucket, Providence and East Providence, Rhode Island, but excludes the Ten Mile subbasin at the southeastern limits of the Blackstone River Basin (see Plate 1-1).

This report is based on information relative to rainfall, runoff, historical flood heights and other technical data bearing upon the frequency and size of floods in the study area. Residents along the river have been interviewed and newspaper files and historical documents have been searched for information concerning past floods. From these investigations and from studies of possible future floods on the Blackstone River, the local flood situation, both past and future, has developed.

Two phases of the flood situation along the river are covered in this report. The first presents a record of the largest known historic floods in the area. The second presents probable flood levels in the event of a recurrence of the historic floods or an occurrence of an Intermediate Regional Flood, or a Standard Project Flood.

Appropriate consideration should be given to the possible future occurrence of historic floods, the Intermediate Regional Flood, and the Standard Project Flood when development in the flood plains of the lower Blackstone River are desired.

Maps, profiles, and cross sections which show the extent of flooding that has been experienced and that which might occur in the future in the Blackstone River areas are included in this report. From the profiles and cross sections, the probable depth of flooding at any location in the study area may be obtained. With this information floor levels for buildings may be planned high enough to avoid flood damage or, at lower elevations, the chance, and hazards of flooding may be recognized.

The New England Division of the Corps of Engineers will, upon request, provide technical assistance to Federal, State and local agencies in the use of the information contained herein and will provide other available data for flood plain management and use.

Background information concerning the authorization of this study and a description of its nature are presented here as a useful introduction to the contents and findings of this report.

PURPOSE AND AUTHORITY

The purpose of this study is to determine the advisability and feasibility of a flood management and related water resources plan for the Blackstone River Basin.

The determination that such a plan is desirable was made with factual information on past and potential floods and by developing and recommending a set of alternative solutions which appear to be economically feasible and to merit further detailed investigations. By using this basic data, an applied judgment was made as to degree of protection needed and probability of engineering, economic, social and environmental feasibility. Individual study elements were either recommended for further analysis or found to be unwarranted and eliminated. Recommendations of this study are presented in the main report.

This report is submitted in partial compliance with seven Congressional resolutions, combined under one resolve adopted by the Committee on Public Works of the United States Senate. These resolutions authorized the Pawcatuck River and Narragansett Bay Drainage Basins (PNB) Study, which includes the Blackstone River Basin. The following are the resolutions that pertain to the Blackstone River Basin:

Resolution adopted on 29 March 1968 by the Committee on Public Works of the United States Senate:

> "That the Board of Engineers for River and Harbor, created under Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report on Land and Water Resources of the New England - New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eight-fifth Congress, with a view to determining, in light of the heavy

damages suffered during the storm of March 1968, in southern New England, the advisability of improvements, particularly in the Pawcatuck River Basin, Rhode Island and in the Narragansett Bay Drainage Basin, Massachusetts and Rhode Island, in the interest of flood control, navigation, water supply, water quality control, recreation, low-flow augmentation, and other allied water uses."

Resolution adopted on 10 July 1968 by the Committee on Public Works of the House of Representatives.

"That the Board of Engineers for River and Harbor is hereby requested to review the reports on the Land and Water Resources of the New England - New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining, in light of the heavy damages suffered during the storm of March 1968, in southern New England, the advisability of improvements, particularly in the Pawcatuck River Basin, Rhode Island and in the Narragansett Bay Drainage Basin, Massachusetts and Rhode Island, in the interest of flood control, navigation, water supply, water quality control, recreation, low-flow augmentation, and other allied water uses."

Resolution adopted on 8 May 1967 by the Committee on Public Works of the United States Senate.

"That the Board of Engineers for River and Harbor, created under Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report of the Chief of Engineers on Blackstone River, Massachusetts and Rhode Island, published as House Document Numbered 624, Seventy-eighth Congress, and other pertinent reports, with a view to determining whether any modifications of the recommendations contained therein are advisable at this time, in the interest of flood control and allied purposes."

Objectives - The basic objective of the PNB Study is to determine the advisability of improvements for flood control, navigation and other allied purposes to meet present and foreseeable long term needs within the study area. The specific objective of the Blackstone River Watershed Study is to provide an implementable flood control plan for areas suffering severe flood damages. To do this, the study used a comprehensive approach to the problems and needs of the watershed. The resultant plan is intended as a wise utilization of basin water and related land resources.

This goal can be attained by reflecting society's informed preferences for attainment of two broad study objectives, as established by the U.S. Water Resources Council.

Environmental Quality (EQ). This objective seeks to enhance the quality of the environment through the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

National Economic Development (NED). This objective seeks to increase the value of the output of goods and services and improve economic efficiency.

For this particular report of Flood Damage Reduction, the planning objective is:

To minimize tidal and riverine flood damages in environmentally, economically and socially acceptable ways.

To meet this objective, alternatives were formulated and evaluated in terms of environmental, economic and social criteria. Three plans were developed.

Facilities are not to be built on the flood plain unless they are either elevated above the 100-year floodstage or are floodproofed to this elevation.

The Blackstone Canal and Old Slater Mill are recorded in the National Register of Historic Places and these sites were regarded as sensitive areas when flood control alternatives were being considered.

Alternatives - To meet the objective -- of minimizing damages -- five broad alternative approaches are available: (1) reduce the extent and frequency of the flooding, (2) minimize the damages that will still occur, (3) reduce the damage potential by limiting development in locations susceptible to flooding, (4) accept the remaining damage as being beyond practicable reduction, and (5) mitigate the suffering from the damage accepted.

Within these broad alternatives, a large number of specific alternative measures are listed in Table 1-1. Measures 1-c, 1-d and 1-e in the table are implemented by large specific projects. The remaining alternatives are essentially policy measures applicable almost everywhere. Most entries are self-explanatory. Description and discussion of each are deferred briefly to the next section so that they can be interpreted along with the evaluation.

TABLE 1-1 ALTERNATIVE FLOOD REDUCTION MEASURES

1. <u>REDUCE THE FLOODING</u>
   - a. Modify hurricanes
   - b. Control the land runoff
     - (1) By land treatment
     - (2) By conservation measures (e.g. wetlands)
   - c. Impound the flood waters (e.g. single & multipurpose reservoirs)
   - d. Improve the channel capacity
     - (1) By channel deepening, widening and realigning
     - (2) By removing natural and man-made obstacles
   - e. Confine the flow (e.g. dikes, flood walls and levees)

2. <u>MINIMIZE DAMAGES FROM THE FLOODING</u>
   - a. Flood proof--voluntarily
   - b. Flood proof--mandatorily
   - c. Forecast, warn and evacuate

3. <u>CONTROL DEVELOPMENT IN THE FLOOD PLAIN</u>
   - a. Public policy inducements
     - (1) Change current usage
       - (a) By multipurpose acquisition
       - (b) By compensable regulations
     - (2) Change future usage
       - (a) By educational policy
         - <u>1.</u> Guidelines on priority uses of flood plains
         - <u>2.</u> Flood plain delineation, mapping and description
         - <u>3.</u> Warning signs
       - (b) By financial policy
         - <u>1.</u> Current use tax
         - <u>2.</u> Tax adjustments
         - <u>3.</u> Graduated mortgage rates
       - (c) By application of other public programs
         - <u>1.</u> Location of utilities, roads and other public services
         - <u>2.</u> Land use policies
           - <u>a.</u> Planned unit development and cluster zoning
           - <u>b.</u> Density transfer
           - <u>c.</u> Wetlands protection laws
           - <u>d.</u> Open space goals
           - <u>e.</u> Other developmental policies and programs
         - <u>3.</u> Health regulations
   - b. Regulate land use
     - (1) By encroachment lines (including channel and harbor lines)
     - (2) By zoning
     - (3) By subdivision regulations
     - (4) By permits (zoning board of appeals) to (1), (2) and (3) above
     - (5) By acquiring development rights in conjunction with regulations
   - c. Directly acquire flood prone land
     - (1) By acquisition of development rights
     - (2) By acquisition with flood damage reduction as primary objective
     - (3) By permanent evacuation and urban renewal

4. <u>ACCEPT THE DAMAGE</u>

5. <u>MITIGATE SUFFERING FROM DAMAGE ACCEPTED</u>
   - a. Insure
     - (1) By voluntary subsidized programs (HUD)
       - (a) Emergency program
       - (b) Regular program
     - (2) By voluntary non-subsidized program (not feasible)
     - (3) By mandatory subsidized program
     - (4) By mandatory non-subsidized program
   - b. Assist in emergencies (rescue and aid)

SCOPE OF THE STUDY

The studies presented in this report encompass the entire Blackstone River Basin and address water resources problems and the potential for solving them. Following completion of the hydrologic and economic analyses, all reasonable alternative plans to solve the area's water resources problems were considered; and several plans were studied in detail that included cost and benefit estimates. Selection of the most feasible plan was made after considering all factors, including comments expressed by concerned agencies, the State of Rhode Island and local interests. The studies were developed only to the depth and detail needed to select a plan and determine its feasibility. A map showing the relationship of the Blackstone River Basin and the PNB study area is indicated on Plate 1-1.

STUDY PARTICIPANTS AND COORDINATION

The Corps of Engineers had the principal responsibility for conducting and coordinating the study and the plan formulation, consolidating information from studies of other agencies and preparing the report.

These studies and investigations were performed with the assistance of the following participating agencies:

U.S. Department of Interior (Fish and Wildlife Service)
U.S. Department of Agriculture (Soil Conservation Service)
U.S. Department of Commerce (National Weather Service)
U.S. Department of Housing and Urban Development
U.S. Department of Interior (Geologic Survey Branch)

Effects of the study alternatives concerning fish and wildlife were analyzed by the U.S. Fish and Wildlife Service.

All studies were coordinated with the appropriate agencies including but not limited to the following:

<u>Federal Level</u>

U.S. Environmental Protection Agency
U.S. Department of Health, Education and Welfare (Public Health Service)
U.S. Departmnent of Commerce (National Marine Fisheries Service)
U.S. Department of the Interior (Heritage Conservation and Recreation Service)

State and Regional Level - Rhode Island

Statewide Planning Office
Historical Preservation Commission
Water Resources Board
Department of Health
Department of Natural Resources (Division of Fish and Wildlife)
Blackstone Valley Sewer District Commission

State and Regional Level - Massachusetts

Central Massachusetts Regional Planning Commission
Department of Environmental Quality Engineering (Division of Waterways)
Department of Environmental Management (Division of Water Resources)

Local Level

City of Woonsocket, Rhode Island
City of Central Falls, Rhode Island
City of Pawtucket, Rhode Island
Town of Cumberland, Rhode Island
Town of Lincoln, Rhode Island
Cumberland, Rhode Island Conservation Commission
Lincoln, Rhode Island Conservation Commission

Private Groups

Audubon Society
Cumberland Preservation Society
Blackstone River Watershed Association
Sierra Club
Pawtucket - Blackstone Valley Chamber of Commerce
Canal, Inc.

Coordination procedures included informal meetings to discuss alternative plans considered or to be considered, review of and comments on the preliminary draft environmental statement for the selected plan, and participation in formal public meetings.

Initial public meetings were held on 12 May 1969 in Providence, Rhode Island and on 15 May 1969 in Uxbridge, Massachusetts to give local residents an opportunity to express their ideas and to comment on possible plans that could be considered. Since that time, numerous informal meetings have been held with various Federal, State, county and local interests. A

final public meeting for the Blackstone River Basin was held on December 7, 1978.

THE REPORT

For clarity of presentation and reference, this report has been arranged into two parts: a main report and eight appendices.

The Main Report is a nontechnical presentation of the feasibility studies for flood and associated water resources problems in the Blackstone River Basin. Included are a description of the study area and existing improvements; problems being experienced and the need for additional protective measures; formulation of the most suitable plan for meeting the need; a summary of the project economics listing the benefits, costs and justification; a division of plan responsibilities between Federal and non-Federal interests; and recommendations for implementing the selected plan.

The technical appendices follow the same general outline as the formulation and evaluation portion of the main report, yet provide complete technical detail on the conduct findings and proposed solutions of the study.

PRIOR STUDIES AND REPORTS

<u>NENYIAC Report</u> - A report by the New England - New York Interagency Committee (NENYIAC) was prepared in the early 1950's. It considers all aspects of the land and water resources of the New England - New York region. Chapter XVII, "Narragansett Bay Drainage Basin," covers the problem of flood control and interrelated water resources problems. It is stated that reduction of flood damages could be obtained by a flood forecasting and warning service coupled with local plans for protective measures to be taken on the basis of such forecasting and warning.

<u>N.E. Flood Studies Report</u> - A June 1963 report was prepared by the U.S. Army Corps of Engineers to review flood control in the Basin. It considers various methods of further reducing flood losses in the basin over and above those losses eliminated by the West Hill Dam and the Worcester and Woonsocket Local Protection Projects. These measures include flood plain zoning, structural modification and floodproofing of buildings.

<u>Report of Study - Blackstone River</u> - This report was published in November 1965 by the Massachusetts Department of Public Works, Division of Waterways and was prepared by Whitman and Howard, Inc.

The purpose of this study was to determine the condition and capacity of the existing streambed, bridges and dams of the Blackstone River in Massachusetts. The study includes a general description of the area and a hydrologic analysis of the watershed plus recommendations for the reconstruction and/or removal of bridges, dams and the stream channel.

Master Manual of Reservoir Regulations - This report was published in June 1966. It presents hydrological data for the watershed and describes the coordinated plan of development for the basin, which consists of a flood control dam on the West River as well as local protection projects. Also presented are procedures for regulating the Blackstone River protective works. The report discusses the impact that regulating the discharges from the West Hill Reservoir would have on the profiles of the 1955 and Standard Project Floods.

Flood of March 1968 in Eastern Massachusetts and Rhode Island - This report was published by the U.S. Geological Survey. Its objective was to present floodflow data that could be used by engineers, planners, public officials and others in conducting hydrologic evaluation of the flood of March 1968.

Flood Plain Information Reports - Developed and published by the New England Division, Army Corps of Engineers, these reports assist State and local governments in developing effective flood plain management programs. The information is developed for the use of planning groups, zoning boards, private citizens, engineering and planning firms, real estate and industrial developers and others to whom it would be valuable. Topics treated in the reports include identification and mappings of areas subject to flooding, compilations of hydrologic flood frequency and flood damage information. General criteria on flood plain use are established to aid State and local agencies in developing land use plans and regulating the use of flood plain areas. Three reports have been completed for communities in the study area. The first was published in June 1971 for Cumberland, Lincoln, Central Falls and Pawtucket, Rhode Island, and the second was written for the town of Auburn, Massachusetts in October 1972. A third report, published in August 1973, was developed for the town of Lincoln, Rhode Island.

Planning Aid Report on Climatology and Hydrology - A September 1972 report for the Southeastern New England Study of Water and Related Land Resources was published by the Corps of Engineers. This report presents climatologic and hydrologic data pertinent to southeastern New England. Included are sections covering climatologic streamflow, peak discharge frequencies, analysis of

rainfall, drought studies and storage-yield relationships.

Reconnaissance Report of the Providence River Group - A published report of the Providence River group, of which the Blackstone and Seekonk Rivers are a segment, was completed in October 1972 by the New England Division, Corps of Engineers. The river group includes the Woonasquatucket and Mosshassuck watersheds in addition to the Blackstone and Seekonk areas. It presents the findings of a preliminary analysis of field reconnaissance and states that certain communities within the total study area have suffered in varying degrees from destructive floods during the past two centuries. The report concluded that population growth and urbanization in the Providence River Group watershed have magnified land development problems in the suburban fringe areas of the core cities. There are many possible solutions for minimizing future flood losses in the Providence River Group watershed; however, preliminary analysis indicates that only the few singularly oriented toward flood control might be economically feasible. The most viable solutions were considered to be multiple purpose structural measures, together with a strong nonstructural measurement program.

Site Preservation for Water Resources Project - Published in January 1973 by the New England Division, Army Corps of Engineers, this report was prepared by Curran Associates, Inc. and developed as part of the Northeastern United States Water Supply Study. The report had three major objectives; to investigate and evaluate methods historically employed in preserving certain tracts of land for future water resource development projects; to collect and interpret data necessary to judge the effects of advance acquisition of such land; and to analyze the history and problems of reservoir site preservation in the State of Rhode Island and develop a plan to overcome the problems.

Flood Insurance Studies - Prepared for the Federal Insurance Administration by other Government agencies and consultants, these studies map eligible communities by risk zones and determine insurance rates. The information provided by the reports enables subject communities to participate in the National Flood Insurance Program. Table 1-2 lists the study area communities currently enrolled in the Flood Insurance Program.

TABLE 1-2

FLOOD PLAIN MANAGEMENT STATUS

Community	Flood Hazard Areas Identified	Status of Flood Insurance	Enacted Flood Plain Zoning Measure
RHODE ISLAND			
Central Falls	Yes	R	Yes
Cumberland	Yes	R	Yes
East Providence	Yes	R	Yes
Lincoln	Yes	R	Yes
North Smithfield	Yes	R	Yes
Pawtucket	Yes	R	Yes
Providence	Yes	R	Yes
Woonsocket	Yes	R	Yes
MASSACHUSETTS			
Blackstone	Yes	R	Yes
Grafton	Yes	E	Yes
Millbury	Yes	R	Yes
Millville	Yes	E	No
Northbridge	Yes	R	No
Sutton	Yes	E	No
Uxbridge	Yes	E	Yes
Worcester	Yes	R	Yes

NOTE: R = Regular
E = Emergency

Southeastern New England (SENE) Report - As part of the program established by the 1965 Water Resources Planning Act, the U.S. Water Resources Council authorized the development of multiple-purpose, coordinated plans for each subregion or major river basin in the nation. The Council also authorized a comprehensive level B study of the coastal basins of eastern Massachusetts, Rhode Island and the southeastern corner of Connecticut. Under the direction of the New England River Basins Commission, a Federal-State study team evaluated existing, 1990 and 2020 needs in the SENE area (including all of the PNB area). The team concentrated on water supply, water quality, recreation, marine management, flooding and erosion, minerals extraction and the siting of electrical power and petroleum facilities. Their report to the Water Resources Council, submitted in March 1976, states that while continuing urban growth in the SENE area can be accommodated, it should be guided to protect fragile resources and make development more efficient.

The SENE Study efforts were closely coordinated with those of the PNB Study. The SENE Study recognized that specific project proposals to resolve the major flood problems in the lower basin were being evaluated by the PNB Study. Therefore, the SENE Study team concentrated its recommendations on regulatory, soil conservation and forestry measures that all basin municipalities should adopt to reduce flood plain encroachment, erosion and nonpoint source pollution.

Water Resources Development Study - This report was prepared for the New England Division, Army Corps of Engineers, by CE Maguire, Inc. in 1974. It consists of three volumes: "Hydrology and Hydraulics," "Economics," and "Plan Formulation."

The "Hydrology and Hydraulics" report, published in May 1974, describes the hydraulics of the Blackstone River and discusses its climatology, streamflow, flood frequencies and stage discharge relations. It includes a history and analysis of floods on the Blackstone River.

The "Economics" report, published in October 1974, presents an overview of the economic characteristics of the people involved with the basin's resources. The rivers floods are then analyzed for their impact on these people.

The "Plan Formulation" volume was published in October 1974 and reviews the findings of the other volumes. It then presents various plans for both local and regional flood protection.

Environmental Report - This report was prepared for the New England Division, Army Corps of Engineers, by Parsons, Brinckerhoff, Quade and Douglas in March 1975. The Corps of Engineers at that time had several flood control remedies under consideration in the Blackstone River Basin of Rhode Island and Massachusetts. This report presents a qualitative investigation of the probable environmental impacts of those flood control projects.

Water Quality Management Plans - Water Quality Management plans were prepared by the Commonwealth of Massachusetts (April 1975) and the Rhode Island Statewide Planning Program (January 1976) for their respective reaches of the Blackstone River. These reports were developed as part of the requirement of Section 303(e) of the 1972 Federal Water Pollution Control Act, as amended. The purpose of these plans is to establish a framework of pollution abatement actions. When implemented through appropriate wastewater treatment methods, water quality will be greatly improved.

STUDY AREA

Study Area - The entire PNB study area includes a small portion of Connecticut (57 square miles), a part of Massachusetts (1,040 square miles) and nearly all of Rhode Island (1,076 square miles).

The study area encompasses 2,173 square miles, which is approximately 3.4 percent of New England and about 15.7 percent of the three southern New England States. The 1970 population within the PNB area was 1,732,000, or about 14.6 percent of New England. The population densities of the three States in relation to the rest of the nation were as follows: Rhode Island - second with 905.4 people per square mile; Massachusetts - third with 727 people per square mile; and Connecticut - fourth with 623.7 people per square mile as compared to the average population density of 57.5 for the entire United States.

The study area is hydrologically divided into five major watersheds: namely, the Pawcatuck River (PK); the Providence River Group (PD), which is comprised of three subwatersheds known as the Blackstone, Ten Mile-Seekonk, and the tri-river complex involving the Woonasquatucket-Moshassuck-Providence Rivers; the Taunton River (TN); the Pawtuxet River (PX); and the Narragansett Bay local drainage area (LD).

RESOURCES AND ECONOMY OF THE STUDY AREA *

Since 84 percent of the Blackstone River's length lies within metropolitan townships (according to the 1970 U.S. Census), the river has an important influence upon, and is greatly influenced by, man and man's creations. Consequently, a general understanding of the study area's resources, development and economy is essential to identifying flood related problems and needs in the area, and to selecting appropriate solutions. The following pages discuss environmental, natural and human resources as well as the area's development and economy.

EXISTING CONDITIONS

Environmental Setting and Natural Resources - Generally elongated in shape, the Blackstone River extends through south-central Massachusetts and northern Rhode Island. Covering 382 and 158 square miles of each State, respectively, it has a total drainage area of 540 square miles.

The basin is bordered by the Thames River Basin on the west and the Merrimack River Basin on the north. The Charles River Basin adjoins on the northeast while the Narragansett Bay Drainage Area borders on the south and southeast. About 46 miles long, the basin has an average width of approximately 12 miles. It occupies the southeastern corner of Worcester County, the southwestern corner of Norfolk County and the northwestern corner of Bristol County in Massachusetts. In Rhode Island, it lies in the northern and northeastern portions of Providence County.

Principal Rivers - The Blackstone River Basin is a region of generally wooded hills and rolling countryside. The tributaries in the upper reaches of the watershed are short and steep, while those in the lower reaches are relatively longer. Thus, there is a tendency for the tributary flows to synchronize with the crest on the main river, resulting in high floodflows.

Originating at the junction of the Middle River and Mill Brook in the southern part of Worcester, Massachusetts, the Blackstone River flows in a generally southeast direction. Its mouth is 44 miles downstream, at the Main Street Dam in Pawtucket, Rhode Island. At this point the river is a tidal estuary and becomes the Seekonk River. It flows south for 7 miles, then feeds into the Providence River in Providence, Rhode Island.

* 1980 Population is included in main report.

There is a total fall of approximately 440 feet along the Blackstone River from its source to sea level. Along the reach from Worcester to Fisherville, a distance of about 10 miles, the river falls 150 feet, about 15 feet per mile. In the next 18 miles to Blackstone, Massachusetts, the average fall is only about 5 feet per mile. The river valley in this reach is broad and flat, having a marked modifying effect on floods in the basin. Downstream of Blackstone, the river drops 75 feet in 3 miles, then flattens out to a rather uniform slope of approximately 11 feet per mile to the tidewater.

The Blackstone River, though the largest, is not the only contributor of riverine benefits and problems to the watershed. The tributaries, because they run through heavily urbanized areas have important influences upon the population and industry of the basin. The succeeding paragraphs provide brief descriptions of the major Blackstone River tributaries.

The Blackstone River headwaters consist of the Kettle, Beaver and Mill Brooks and the Middle River. Other important tributaries are the Quinsigamond, Mumford, Branch, Mill and Peters Rivers and Abbott Run.

Kettle Brook, located entirely in Massachusetts, originates in the town of Paxton and drains an area of 32.8 square miles. The brook flows southeasterly through Leicester and Auburn; then, in Stoneville, it turns north and flows toward Worcester. Kettle Brook terminates at its confluence with Beaver Brook, where together they form the Middle River. Included in the Kettle Brook watershed are many reservoirs providing water supply to the city of Worcester, as well as low flow augmentation for downstream industrial purposes.

With a total drainage area of 15.6 square miles, Beaver Brook originates near the city of Worcester's northern border. It flows southward for approximately 4.5 miles before joining Kettle Brook to form the Middle River. The Beaver Brook watershed is densely populated and has few ponds, lakes or reservoirs.

Mill Brook begins in the town of Holden, Massachusetts, then flows southward to its confluence with the Middle River in the southern portion of Worcester, Massachusetts. Throughout most of its 7.5 mile length, the brook is enclosed in an underground conduit. The terrain along Mill Brook's course is very hilly and heavily urbanized.

Flowing generally southeasterly for a distance of about 2.5 miles, Middle River passes through a wetland area and two small ponds. It intercepts Mill Brook to form the Blackstone River at

the American Steel and Wire Company Dam northeast of the Quinsigamond Village in Worcester. The total drainage area of the Middle River Basin is 65 square miles.

The Quinsigamond River is approximately 13 miles long, 8 miles of which are a succession of natural lakes. The basin lies in the towns of Boylston, West Boylston, Shrewsbury, Grafton, Millbury and the city of Worcester, all in Massachusetts. The Quinsigamond River Basin drains an area of 37 square miles.

Lake Quinsigamond, Flints Pond and Hovey Pond are the largest of the lakes and have been chiefly responsible for the development of the watershed. Areas along the periphery of the lakes are heavily developed in residential properties.

The Mumford River rises from a system of natural lakes, ponds and reservoirs in the towns of Oxford, Douglas and Sutton in Massachusetts. It then meanders eastward toward its confluence with the Blackstone River, about a half-mile east of the center of Uxbridge. About 17 miles long, the river has a drainage area of 58 square miles. Numerous impoundments, used to store process water for finishing textile goods, can be found throughout the basin. The economic character of the basin varies from rural in the upper reaches to heavily industrialized in the lower portions.

West River originates in the Upton State Forest, three miles northeast of the center of Grafton. Situated entirely in Massachusetts, it flows southward through Upton and Northbridge until it feeds into the Blackstone River, about 12 miles downstream from its head. The total drainage area is 35 square miles; approximately 80 percent of this is controlled by the existing Army Corps of Engineers West Hill flood control reservoir. This multipurpose reservoir is used for recreation as well as for storage of floodwaters. The basin consists of low rolling wooded hills and broad valleys with scattered small ponds and swampy areas.

Branch River is the largest tributary in the Blackstone River Basin with a total drainage area of 96 square miles. Eighty-seven percent of the area is in Rhode Island with the balance in Massachusetts. The Branch River comes into existence at the confluence of the Clear and Chepachet Rivers, in the town of Burrillville, Rhode Island. The river flows northeasterly for about seven miles to its intersection with the Blackstone River near Blackstone, Massachusetts. The basin boasts many natural lakes and ponds. Manmade reservoirs, which were originally constructed for use by the textile industry, are scattered along the full length of the river.

From its source at North Pond, Mill River runs southerly for 15 miles through the towns of Mendon and Blackstone, Massachusetts. It joins the Blackstone River immediately above the U.S. Geological Survey gaging station No. 1125 at Woonsocket, Rhode Island. The drainage basin encompasses approximately 35 square miles, the majority in Massachusetts. The largest impoundment in the basin is Harris Pond in the town of Blackstone. It is one of Woonsocket's main sources of water supply. Most of the Mill River's drainage basin consists of gently rolling wooded hills.

Peters River originates in Bellingham, Massachusetts, just north of Silver Lake. It flows southwesterly for approximately 3.5 miles and then crosses the Massachusetts - Rhode Island State line at Woonsocket. About a mile farther downstream, it joins the Blackstone River via a pressure conduit at the lower Woonsocket local protection project.

Characterized by many swamps and ponds, Abbott Run flows from the towns of Wrentham and Cumberland along the Massachusetts - Rhode Island border. Near its origin, it is impounded in the Diamond Hill Reservoir which supplies water to the city of Pawtucket, Rhode Island. The run then flows southward, joining the Blackstone River in the village of Valley Falls, Rhode Island. Abbott Run has a drainage area of 27 square miles.

<u>Climate</u> - New England's climate is aptly described by the adage, "If you don't like the weather wait a minute, it'll change." The weather of the Blackstone River Basin is characterized by this same variability, with frequently alternating periods of precipitation and fair weather. The basin winds are dominated by the general airflow known as the "prevailing westerlies." It is visited by continental cyclones and by coastal storms of both tropical and extra-tropical origin. Thunderstorms occur over the basin during all seasons and may be of local or frontal nature.

The year-round average temperature of the Blackstone River Basin is approximately 48.7°F (averaging the values of 47.0°F at Worcester, Massachusetts and 50.5°F at Providence, Rhode Island).* Monthly mean temperatures in Worcester vary widely between 24.0°F in January and 70.0°F in July. Providence, Rhode Island is also

*The numerical information presented in this climatology is based on data for the period 1935 - 1974, published in the National Weather Service publication, <u>Local Climatological Data, Annual Summary, 1974, Worcester, MA</u> and <u>Local Climatological Data Annual Summary, 1974, Providence, RI.</u>

changeable, with a minimum of 29.2°F in February and a maximum of 72.7°F in July. Extremes above 100°F and below 0°F are occasionally, though rarely, experienced. Mean monthly temperature values are available for Worcester and Providence and are presented in Table 1-3.

Snowfall in the Blackstone River Basin averages from 38 inches per year in the south to nearly 75 inches annually in the inland north. Surveys conducted in recent years indicate that annual water content of the snowfall over the basin rarely exceeds three inches; however, values up to six inches are occasionally observed in the upper basin. Melting snow often results in moderately high springtime discharges, but runoff from this source alone seldom results in major flooding. It is possible, though, for the snowmelt to combine with heavy rainfall and produce severe floods. Table 1-3 contains data on average monthly snowfall.

Four general classes of storms occur in the Blackstone River Basin: continental, extra-tropical coastal, tropical coastal and thunderstorms. Continental storms originate over the Pacific Ocean and western North America, then move east, following "storm tracks" determined by the jet stream and the flow of the upper level westerlies. The Blackstone River Basin lies within the convergence zone of these storm tracks and experiences continental storms at approximately regular intervals throughout the year.

Extra-tropical coastal storms, locally known as "nor'easters," develop through atmospheric wave action off the coast of the Carolinas. The storms travel in a northeasterly direction, closely paralleling the coastline. Nor'easters combine slow forward movement with a characteristically large rainshield to produce substantial precipitation totals. These storms invade the area most frequently during the late autumn, winter and early spring.

Tropical coastal storms originate in the Caribbean or warm Gulf Stream and may intensify into hurricanes. Moving toward the mainland in a westerly to northwesterly direction, they normally move inland far to the south of New England and then bear east, returning to the Atlantic Ocean still well south of Cape Cod. Under these conditions, tropical storms have little effect on the Blackstone River Basin. Occasionally though, a storm will be deflected from a normal path and pass over or near New England (see Figure 1-1). It then becomes the basin's most serious severe weather problem. With these tropical storms come very strong winds, intense precipitation and abnormally high, wind driven tides known as the "storm surge." The months of July through October present the highest probability of tropical storms and

TABLE 1-3

MEAN MONTHLY TEMPERATURE, PRECIPITATION AND SNOWFALL
WORCESTER, MA AND PROVIDENCE, RI

	WORCESTER, MA			PROVIDENCE, RI		
Mo.	Ave. Temp.	Precip.	Snowfall	Ave. Temp.	Precip.	Snowfall
	°F	"	"	°F	"	"
Jan.	24.0	3.33	15.5	29.3	3.55	9.5
Feb.	25.2	3.49	19.6	29.2	3.29	10.1
Mar.	32.7	4.02	16.6	37.6	3.71	9.5
Apr.	45.0	4.02	4.2	47.6	3.58	0.7
May	55.3	3.92	T	57.8	3.16	0.0
Jun	65.0	3.49	0.0	67.0	2.96	0.0
Jul	70.0	3.39	0.0	72.7	3.06	0.0
Aug	68.1	4.34	0.0	71.0	3.58	0.0
Sep.	60.5	4.14	0.0	63.9	3.33	0.0
Oct.	51.0	3.80	0.6	54.0	3.02	0.1
Nov.	39.4	4.71	3.6	43.3	3.70	0.4
Dec.	27.8	4.37	14.5	32.7	3.84	7.7
An	47.0	47.02	74.6	50.5	40.78	38.0

The above was determined from data for the years 1935 - 1974 as published in the following National Weather Service Publications:

Local Climatological Data, Annual Summary, 1974, Worcester, Mass.
Local Climatological Data, Annual Summary, 1974, Providence, RI

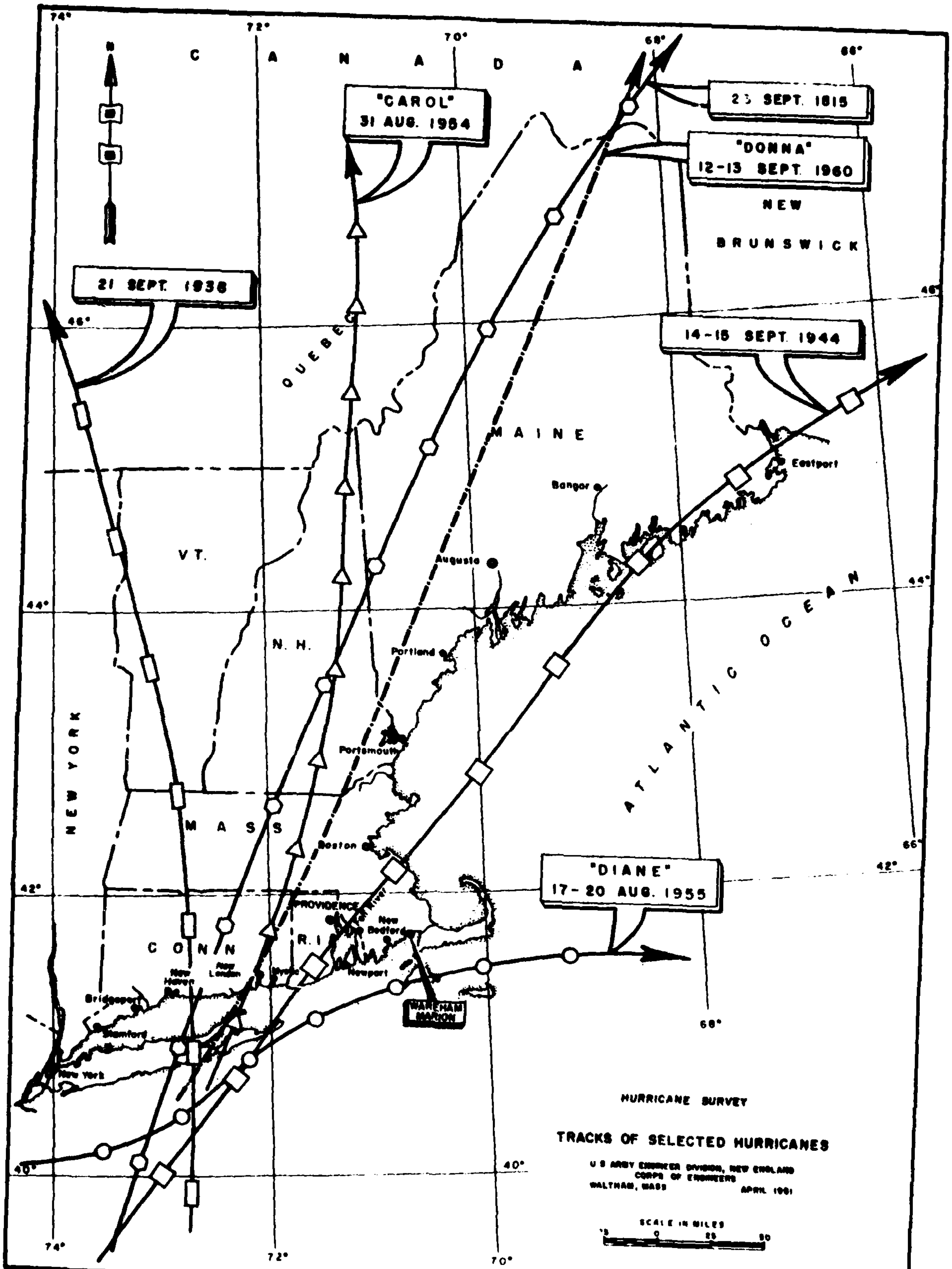
hurricanes.

Thunderstorms are violent phenomena with high winds and heavy rainfall and are sometimes accompanied by hail. The storms are usually compact and fast-moving, resulting in only local flooding if any at all. Widespread flood conditions develop with the occurrence of an exceptionally large or slow-moving thunderstorm; from several storms occurring together in a small area; or from a rapid succession of cells moving through the region. Thunderstorms can be of air mass (local) or frontal origin. Occurring an average of 20 to 30 days a year, they are most frequent from mid-spring to early fall.

When rainfall is below the monthly or yearly average for an extended period of time, the area experiences drought conditions. Droughts in the Blackstone River Basin have seriously affected both water supply and riverflow. The New England drought of 1963 -1966 was the Blackstone River Basin's longest drought in 200 years of record. The severity of the drought conditions was aggravated by failure of the towns and cities in the basin to adequately plan for increased water demand. This laxness developed during a period in which the rapidly increasing water demand was offset by above normal rainfall. The accumulated deficiency in the average runoff of the Blackstone River at Woonsocket, Rhode Island was 27 inches for the years 1964-1967. This was equivalent to about one year's normal runoff.

Topography - The topography of the Blackstone River is generally hilly, with higher elevation and narrower valleys in the northern portion. The soil is of glacial origin and the exposed rock is mostly granite. In several places the river has worn its bed down to ledge rock, thereby creating a number of natural falls. These falls offered favorable power sites for manufacturing towns and villages along the stream; the valley is also well developed for truck gardening. The elevation of the watershed varies from a maximum of 1,395 feet above mean sea level in Paxton, Massachusetts near Worcester, to mean sea level in Pawtucket, RI at the lower end.

Geology - Sections of two major physiographic regions comprise the Blackstone Basin. The New England Upland Region, constituting more than two-thirds of the basin, is an area of moderate relief although it is hilly in appearance with elevations generally over 300 feet that range to a maximum of over 1,000 feet above sea level. To the southeast, the upland area is bordered by the low hills and plains of the Narragansett Bay Basin where elevations are generally less than 200 feet above sea level. Except for modifications of topography by glaciation and by more recent



CANADA
"CAROL"
31 AUG. 1954
23 SEPT. 1815
"DONNA"
12-13 SEPT. 1960
NEW BRUNSWICK
21 SEPT. 1938
14-15 SEPT. 1944
QUEBEC
MAINE
Bangor
Eastport
VT.
Augusta
N. H.
Portland
ATLANTIC OCEAN
NEW YORK
Portsmouth
MASS
Boston
"DIANE"
17-20 AUG. 1955
PROVIDENCE
New Bedford
CONN
R.I.
Newport
Bridgeport
Stamford
New York
WAREHAM MARION
HURRICANE SURVEY
TRACKS OF SELECTED HURRICANES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS
APRIL 1961
SCALE IN MILES

FIG. 1-1

erosion and depositions by streams, these physiographic regions will reflect the nature of the underlying bedrock. Those of the upland region are mainly igneous in the form of alternate bands of granites with subordinated elongated masses of gneiss, schist, phyllite and quartzite representing various degrees of metamorphism of original sediments such as sands, silts and clays. These rocks are strongly crystalline in character and relatively resistant to erosion so that the general direction of the valleys and consequently the drainage over much of this region is structurally controlled by the bedrock formations which trend about northeast-southwest. In contrast, the subdued topography and consequent irregular drainage patterns of the Narragansett Bay Basin are caused by less resistant sedimentary rocks consisting mostly of shales, sandstones and conglomerates.

The present day topography of the Blackstone Basin was formed by a long period of preglacial stream erosion that dissected the area into a systematic arrangement of rounded bedrock hills and intervening well-drained valleys. During glacial times, the topography was somewhat modified by erosion and deposition of a continental glacier similar to those in Greenland and Antarctica today. Moving southeasterly, the glacier smoothed off the irregularities of the bedrock hills and deepened some of the valleys; and, as it melted away, deposited an irregular mantle of drift in the valleys and on the slopes so that there was a general lessening of the relief. The glacial drift includes nearly all of the unconsolidated materials covering the rock surfaces today. These materials may be simply divided into two types, stratified and unstratified drift. The stratified materials, termed outwash, were deposited as separate layers of gravel, sand, silt or clay carried by meltwater streams flowing from the ice sheet. These outwash deposits have their greatest accumulation on the floors and walls of the larger valleys such as that of the Blackstone River. The unstratified materials, known as "till," consist of unsorted materials of all sizes accumulated beneath the ice as it advanced and deposited fragments. They are imbedded in a matrix of sand, silt and/or clay which, if tightly compacted by the weight and movement of the ice, become difficult to excavate and, therefore, may be locally referred to as "hardpan." Till has wide distribution in the region, generally occurring as a rather thin blanket over the bedrock surface with its greatest thickness in some of the valleys.

Other than aiding in modification of the preglacial topography, the extensive deposits of till and outwash have disarranged the well-developed system of preglacial drainage. This is evidenced by the many swamps and ponds and by present day streams flowing high above or completely out of sections of their

preglacial channels, now filled with glacial deposits. At the West Hill dam site of the West River, a tributary to the Blackstone in Massachusetts, test borings show the present river valley is located over a much larger preglacial valley buried by outwash deposits nearly 100 feet deep. At locations on the Blackstone River, several natural dam sites such as at Woonsocket were provided where the river diverged from its preglacial course to flow over bedrock ridges, creating falls.

Since the last glacial period, there probably has been slight uplift of the region, some renewed erosion in the larger stream valleys and filling in of ponds with vegetation; but the topography of today remains essentially that of the late postglacial time of at least 12,000 years ago.

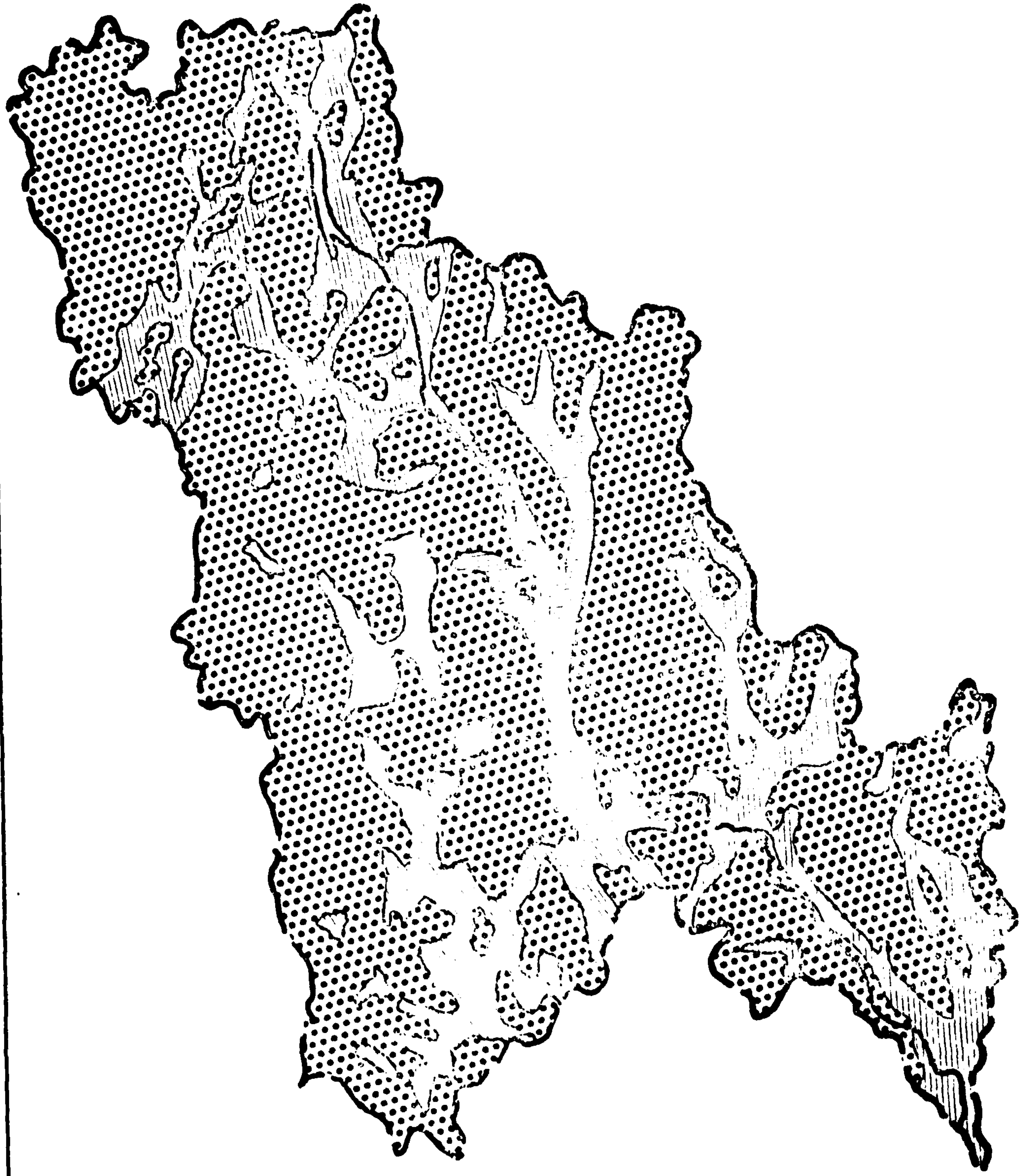
Mineral Resources - Sand and gravel are the only minerals currently being mined in the Blackstone Basin where 13 sand and gravel processing plants are active. These plants are located in Auburn, Grafton, Millbury (2), Shrewsbury (2), Sutton (2) and Uxbridge, Massachusetts. In the Rhode Island portion of the basin, plants are located in Cumberland (2) and North Smithfield (2). Most of the raw material for the plant is obtained from nearby sources but some is mined and trucked from more distant areas both inside and outside the basin. In addition, quantities of sand and gravel are obtained from bank-run (unprocessed) operations.

Most of the sand and gravel processed in the basin is used in ready-mix concrete and hot-mix asphalt. Although stone is not produced in the basin, crushed stone is readily available from operations located in adjacent areas.

Glacio-fluvial deposits of stratified sand and gravel (as shown on Figure 1-2) provide the raw material for the processing plants. The areas considered for inundation by the Nipmuc and Lackey Reservoirs generally fall within glacio-fluvial zones of potential sand and gravel mining sources.

Producers in the basin have indicated that they have undeveloped reserves of sand and gravel at additional sites both within and outside the basin. However, according to projections prepared by the Bureau of Mines*, available sand and gravel resources in the basin are not adequate to meet future needs.

*Blackstone, Ten Mile and Woonasquatucket-Moshassuck River Basin Report - Minerals, prepared for NERBC by the Bureau of Mines, U.S. Department of the Interior, July 1973.



LEGEND
TILL DEPOSITS - MIXTURE OF SAND, GRAVEL & BOULDERS
GLACIOFLUVIAL DEPOSITS - STATIFIED SAND & GRAVEL
SWAMP & MARSH DEPOSITS - SILT, SAND, CLAY, & ORGANIC MATERIAL

N

2 1 0 2
MILES

BLACKSTONE RIVER WATERSHED SURFICIAL GEOLOGY MAP

FIG. 1-2

Although deposits are abundant, many resource areas are not available for mining because of zoning, groundwater involvement or use of the land for other purposes. As nearby sources are exhausted, transportation costs increase due to the greater distances of sources from processing plants.

Ground Water - Till 10 to 20 feet thick often covers the bedrock in the upland areas. Several billion gallons of water are stored in porous voids in the till layer and in open fractures in the upper few hundred feet of bedrock. Wells typically yield between 2 and 15 gallons per minute (gpm).

Throughout most of the Blackstone Basin, the stratified-drift aquifer is very narrow, averaging 40 feet thick or more over an average width of less than 500 feet. The thickest and most transmissive part of the aquifer is beneath the river. Yields of 200 gpm and greater are obtainable from many wells placed close to the river. The yield of the stratified-drift aquifer is dependent in part upon the rate at which infiltration can be induced from the river.

The chemical quality of the groundwater is generally good, with the exception of the presence of high concentrations of manganese. Groundwater is generally soft to moderately hard, slightly acidic and has a low to moderate dissolved-solids content. The quality of the groundwater in the Blackstone River Basin is excellent.

Most of the dissolved solids in the groundwater are derived from soil and aquifer materials. In the Blackstone River Basin, most of the minerals in the soils and subsurface materials are only slightly soluble; hence, the dissolved-solids content of the groundwater is relatively low, generally less than 150 milligrams per liter (mg/l). Concentrations of minerals in the groundwater, with the exception of iron and manganese, are well below limits set by the United States Public Health Service for drinking water.

The chemical quality of groundwater has been slightly affected by septic tank and cesspool effluent, fertilizers, deicing salts from highways, leachate from sanitary landfills and infiltration from the degraded streams of the basin. The principal effect of these wastes has been a slight increase in hardness as well as in chlorides, sulfates and nitrates. The presence of high manganese concentrations in the groundwater is the principal water quality problem in the study area because its removal can be costly and difficult.

Water Supply - The water supply systems located in the Basin are generally small in capacity. Only 4 of the 26 systems can produce more than 2.0 million gallons per day (mgd). Of the 26 systems, 6 operate in Rhode Island while the remainder serve Massachusetts. Five of the systems are privately owned and operated, while 21 are publicly owned.

Both ground and surface sources are used by Rhode Island municipalities for water supply. The city of Pawtucket has the largest system, with an available safe yield of 20.7 mgd. The only town lacking a public water supply system is Glocester, which obtains all of its water from individual private wells.

Groundwater is the primary source of supply outside of the Worcester area in the Massachusetts portion of the basin. The largest surface water supply serves the city of Worcester and has a total safe yield of 32.5 mgd. It consists of a series of reservoirs in the Quinapoxet River Basin in Princeton and Holden and two wells adjacent to Lake Quinsigamond. The town of Millville is the only municipality in the basin in Massachusetts not served by a public water supply system, relying instead on individual wells for supply.

In 1970, approximately 57 mgd, from both ground and surface sources, were supplied to users in the Blackstone River Basin, with 23 mgd going to Rhode Island and 34 mgd serving Massachusetts.

A summary of the sources of water supply in each of the towns in the Blackstone Basin is shown in Table 1-3. The existing water supply systems of the Blackstone Basin in Rhode Island and Massachusetts are shown in Tables 1-4 and 1-5 respectively.

Water Quality - The existing surface water quality in the Blackstone River Basin ranges from Class A (suitable for all uses including water supply) in Abbott Run, to Class E (nuisance condition) in the upper, more heavily developed reaches.

The Blackstone River is the recipient of large amounts of treated and raw domestic and industrial sewage. The riverwater in many reaches is characterized by offensive tastes and odors, high turbidity, high concentrations of suspended and organic material and high bacterial counts as well as low dissolved oxygen (DO) levels. With this large initial load of pollutants, and with many municipal and industrial waste loads added by towns along its course, the Blackstone River is considered less than "C" quality in many reaches.

Some wastewater treatment plants were built in the Blackstone River Basin when the area was experiencing rapid industrial growth during the 1920's. However, many of these facilities lack sufficient capacity to handle today's higher waste flows and, in some cases, raw wastes are discharges directly into streams.

With the advent of Public Law 92-500, a number of new or improved treatment facilities have been constructed on the major sources of waste discharges and water quality in many reaches has significantly improved.

Quality of water in the Blackstone Basin should improve as more advanced and efficient wastewater treatment processes are constructed. The dissolved-solids content, however, will probably increase as the flow increases since municipal and industrial wastewater treatment plants remove little, if any, of the dissolved solids.

Vegetative Cover - The Blackstone River Basin lies near the northern extremity of the Appalachian Oak Forest. Oak and hickory are predominant in most of the basin with maple, birch and beech characteristic of the adjoining Northern Hardwood Forest that grows on the uplands around the western and northern edges of the basin.

Outside the urbanized areas of the basin, the land is mostly forested and has scattered farms and pasture. The oak-hickory forest has little current economic value except for use as firewood or house lots. White pine, occurring as a successional transition between abandoned fields and the climax hardwood forest, are valued for their timber but are becoming increasingly rare.

The region's extensive and widely scattered upland swamps and marshes, results of glacial scouring of the landscape and sedimentation in the stream course, contain a great variety of vegetation and are valued as wildlife habitat as well as natural drainage regulators.

Fish and Wildlife - The Blackstone planning area has few outstanding fish and wildlife habitats. Insufficient and/or low quality habitat cannot support even existing demands. The U.S. Fish and Wildlife Service estimates that about 40 percent of publicly and privately owned land in the planning area is open to hunting. Twenty-seven percent of the area's ponds (10 acres or larger) have guaranteed public right-of-way. Most of the planning area's streams are privately owned with public access at the landowner's discretion or are completely prohibited.

TABLE 1-4

EXISTING WATER SUPPLY SYSTEMS - BLACKSTONE RIVER BASIN
RHODE ISLAND

Name	Towns Served	Avg. 1975 Demand (mgd)	Type of Source	Total Safe Yield (mgd)	Comments
Pawtucket Water System	Cumberland	1.49	Reservoirs	14.5	It is estimated that this source will be inadequate to meet future demands. (a)
	North Providence	0.55			
	Pawtucket	10.96	Wells	5.0	
	Central Falls	2.67			
Harrisville Fire District	Burrillville	0.178	Wells	0.295	-----
Pascoag Fire District	Burrillville	0.28	Wells	1.08	-----
	Glocester	0.48			
Private Source - Wallum Lake	Zambarano Hospital in Burrillville	N.A.	Wallum Lake	0.20	It is estimated that this source will be inadequate to meet future demands. (a)
Town of Cumberland Water Department	Cumberland	1.78	Sneech Pond	0.60	-----
			Wells	2.92	
Woonsocket Water Department	Cumberland	.01	Reservoirs	3.50	Development of new sources with high quality water will be necessary to meet future demands. (a)
	Woonsocket	4.81			
	North Smithfield	0.34	Mill River-Harris Pond (b)	5.0	
			Wells	1.85	
Town of Lincoln Water Department	Lincoln	1.927	Wells	5.50	
North Smithfield	North Smithfield	0.045	Wells	0.05	

NOTES: (a) According to the Preliminary Single-Purpose Plan Report, prepared for the New England River Basins Commission by the Environmental Protection Agency.
(b) The Mill River source of 5.0 mgd is held in reserve because of the poor quality of water.
N.A. Data not available.

TABLE 1-5

EXISTING WATER SUPPLY SYSTEMS - BLACKSTONE RIVER BASIN
MASSACHUSETTS

Name	Towns Served	1975 Demand (mgd)	Type of Source	Total Safe Yield (mgd)	Comments
Auburn Water District	Auburn	0.69	Wells	2.41	-----
Pakachoag Water Company	Auburn	0.10	Artesian Well	0.15	-----
Elm Hill Water District Woodland Water District John Olshewski Water Co.	Auburn	N.A.	Purchased from Worcester Water Department	0.13	------
Blackstone Water Department	Blackstone	0.43	Wells	0.93	New sources are needed to meet future demands.(a)
Douglas Water Department	Douglas	0.15	Wells	0.84	-----
Hopedale Water Department	Hopedale	0.343	Wells	0.504	New wells are needed to meet future demands. (a)
Grafton Water Co. and So. Grafton Water District	Grafton	0.85	Wells	1.82	-----
Milford Water Co.	Hopedale	0.34	Wells	0.50	-----
Mendon Water Department	Mendon	0.031	Purchased from Milford Water Co.	0.50	------

TABLE 1-5 (Cont'd)

Name	Towns Served	1970 Demand (mgd)	Type of Source	Total Safe Yield (mgd)	Comments
Massachusetts Water Works Co. Water District Maple Hillside	Millbury	1.22	Wells	2.0	New sources are needed to meet future demands. (a)
Northbridge Water Company	Northbride	N. A	Wells	N. A	New sources are needed to meet future demands. (a)
Whitinsville Water Dept.	Northbridge	1.58	Reservoir Wells	N. A 3.10	-------
Shrewsbury Water Dept.	Shrewsbury	1.965	Wells	8.78	-------
Wilkinsonville Water District (WWD) and Manchuag Water District (MWD)	Sutton	.064	WWD Wells	0.41	-------
Upton Water Department	Upton	0.176	Wells	0.40	New sources are needed to meet future demands. (a)
Uxbridge Water Department	Uxbridge	0.60	Wells	2.85	------
Worcester Water Department	Worcester Grafton State Hospital	22.40	Reservoirs Wells	26.80 5.70	-------

NOTE: (a) According to the Preliminary Single-Purpose Plan Report, prepared for the New England River Basins Commission by the Environmental Protection Agency.

N.A. - Data not available.

Species Present - The upper reaches of West River and Warren and Center Brooks provide habitat for brook and brown trout, while the lower West River supports a warm water fishery with largemouth bass, chain pickerel, yellow perch and bluegill as the most important game fish. Upland wildlife includes the cottontail rabbit, ruffed grouse, gray squirrel, red fox, raccoon, woodchuck and woodcock. The whitetailed deer is the only big game animal found in the project area. The West Hill Dam reservoir constitutes some of the best habitat available in this part of the State, although deer populations and harvests are below average. Fur animals such as mink and muskrat are not abundant, although some trapping for these species does occur.

A local ornithologist has compiled a list of 209 species of birds in 16 different taxonomic orders that have been observed in the Blackstone River valley. Waterfowl use of the wetlands along the West River is moderate, and 21 species of ducks, geese and swans have been reported. With regard to relative abundance in the vicinity of the West Hill Dam, the species have been further classified as: abundant, 18 species; common, 76 species; uncommon, 90 species; and rare, 25 species. In addition, the following seven birds, which have been sighted in the valley, appear on a list of Rare and Endangered Plants and Animals in Massachusetts (February 1973) prepared cooperatively by the U.S. Department of the Interior, the Soil Conservation Service, the Massachusetts Division of Fisheries and Game and the University of Massachusetts:

Species	Status
Osprey	Undetermined
Black crowned night heron	Undetermined
Southern bald eagle	Endangered
Peregrine falcon	Endangered
Eastern bluebird	Undetermined
Marsh hawk	Undetermined
Purple martin	Undetermined

The report defines an endangered species as "...one whose survival in Massachusetts is in jeopardy. Its peril may result from loss of habitat, change in habitat, overexploitation by man, predation, adverse interspecies competition or disease. An endangered species must receive help or extinction probably will follow." A species whose status is undetermined "...may be rare or endangered in Massachusetts. Information currently available is inadequate to evaluate its status accurately. More information is needed since the species could now exist in dangerously low numbers in the State." The U.S. Department of the Interior's "Red

Book" includes both the southern bald eagle and the peregrine falcon as endangered species on a national basis.

Management- Approximately 8,000 brook, brown and rainbow trout are stocked annually in the West River in the towns of Grafton, Upton and Uxbridge. The Division of Fisheries and Wildlife stocks trout at 25 locations between Silver Lake, adjacent to Route 140 in Grafton, and Route 16 in the village of Wheelockville, town of Uxbridge. Center Brook is stocked at five sites from Upton Center to the Brook's confluence with the West River in the West Hill Reservoir area. Several fishermen's access trails are also maintained on Government-owned land under license to the Division of Fisheries and Game.

The upper West River and tributaries constitute an important cold water fishery resource that is substained largely by stocking of legal sized trout, although there is some natural reproduction. The poor water quality in many of the streams in the Blackstone River Basin has inhibited trout fishing, yet demand for this recreational activity is high.

Fisheries development in the many ponds of the basin would be quite possible, were it not for severe pollution of all major tributaries and the Blackstone itself. (A major percentage of the low flow in summer is effluent from sewage treatment plants.) New ponds could be created in several towns and stocked with fish when pollution is eased, particularly along the main stem of the Blackstone.

Several dams have been built along the river, adding another obstacle to restorations of anadromous fish -- those which swim upstream from saltwater to spawn in freshwater. Fish ladders, pollution abatement, fish stocking programs and acquisition of streambanks would improve this resource.

Destruction of wildlife habitats is the biggest single threat to the variety of wildlife in the basin. Diligent land use planning or public purchase of lands is needed to halt this uncontrolled reduction. Although both Rhode Island and Massachusetts have enacted protective legislation, exemptions for agricultural production and insufficient enforcement and protection are lessening the effectiveness of the laws.

Aesthetic Conditions - While rivers generally enhance landscape, pleasant scenes along the Blackstone within the impact area are somewhat limited, especially along its lower reaches. Here the river is polluted and lined with a large number of industrial and commercial facilities. The water course offers more scenic views

in the middle reaches of the river and its impacted tributaries, though these are often hidden because of restricted physical or visual access.

Uxbridge Area - At the Bernat textile plant in Uxbridge, scenic views are also somewhat limited. The plant is generally shielded from nearby activities (along Main Street in Uxbridge Center) by trees and an abrupt change in elevation on the Main Street side. The only significant view here is downstream from the Mendon Street Bridge, where one can see a tight curve in the river that is framed by a wooded, rather steep slope on the right bank and the Bernat plant on the left. There are very few residences in this area.

Nipmuc River - The Nipmuc River flows through a wooded, rural area and is of excellent water quality; however, access to this area is somewhat restricted. A number of residences have been built here (primarily along Round Top Road), though few have views of the river.

Berkeley Area - The Berkeley Industrial Park is highly visible in the Berkeley area of Cumberland. Set on a large tract of sparsely vegetated flood plain partially covered by grassy fields. The west bank of the river is densely wooded and supports several single family homes on its moderately sloped terrain.

Old Slater Mill Dam - Within the vicinity of Old Slater Mill Dam in Pawtucket, industrial facilities and dense urban developments allow few glimpses of natural settings. However, the pond created by the dam can be aesthetically pleasing, particularly for visitors to Old Slater Mills. The Broad Street Bridge offers many an excellent vista of Old Slater Mill and Dam.

Historic and Archaeological Resources

Prehistoric populations near the Blackstone lived primarily by hunting, gathering, and fishing. Anadromous fish were probably taken in season, and agriculture was adopted after about AD 1000. Most sites were probably on high terraces above flood levels.

European settlements in the basin began in the 1630's, and numerous small grist and saw mills were constructed along the river during the 17th and 18th centuries. With the development of the American textile industry in the early 19th century, numerous textile mill villages developed along the Blackstone. Many of these, such as Pawtucket and Central Falls grew into densely populated cities during the course of the century to transport freight and passengers between Providence and Worcester, but was

soon rendered obsolete by railroad construction on a parallel route up the valley.

Today, numerous 19th century factory sites and structures, as well as millworkers' housing and related features remain as testimony to the unique industrial heritage of the Blackstone Valley. Several structures have been placed on the National Register of Historic Places, Slater Mill in Pawtucket, the Berkeley Mill Valley in Cumberland, and a portion of the Blackstone Canal in Lincoln. The Berkeley Mill Village is outside and to the east of the proposed local protection project, while the Blackstone Canal follows the river's west bank opposite the project site.

HUMAN RESOURCES

Population - Thirty-eight communities (29 in Massachusetts and 9 in Rhode Island) lie wholly or partially within the Blackstone River Watershed (see Figure 1). Eighty-four percent of these communities fall within either of two Standard Metropolitan Statistical Areas (SMSA), the Worcester SMSA or the Providence-Pawtucket-Warwick (PPW) SMSA. In 1970, the population of the former was 344,320 and the latter was 910,781. The Worcester SMSA grew by 15,422 people or by 4.7 percent between 1960 and 1970. The city of Worcester declined by 10,015 people or 5.4 percent while the suburbs grew by 25,437 people or 17.9 percent. The PPW SMSA grew by 89,680 people or 10.9 percent between 1960 and 1970 despite a loss of 33,444 people from its older core municipalities of Providence, Pawtucket, and Central Falls.

Significant growth in the Rhode Island towns of Cumberland, Lincoln, Smithfield, North Smithfield, and Glocester is an indication of a centralization of the Providence core, overlapped to a lesser extent by a similar decline of Woonsocket as an urban center. In Massachusetts, Bellingham, Blackstone, and Mendon exhibited significant population increases centered on Woonsocket while Millbury, Shrewsbury, and Sutton showed similar growth centered on Worcester. Overall the five core cities influencing basin population lost 8 percent of their 1960 population over the decade while the 21 suburban and rural towns with significant portions of their area lying in the basin grew by 24 percent.

Table 1-6 displays the population changes in basin communities over the 1960 to 1970 decade, and changes between 1970 and 1975. The data is presented for those 24 communities who have significant portions of their area lying within the basin. In general, the metropolitan core cities have been declining in

population while the suburbs and rural towns have been growing. This pattern of change, declining older centers and growth on their periphery, is expected to continue into the future, perhaps with greater dispersion from the Boston SMSA to the further-out towns as local zoning restrictions tending toward ever larger land costs in the closer-in towns limit their growth.

The impact area consists of the eleven communities along the main stem of the Blackstone that experience significant flood damages. Seven of these are in Massachusetts, the other four in Rhode Island. Total population of these communities is about 190,000 and represents about one third of the population in the basin communities. The impact area reflects the overall basin trends with continued population decreases noted in the urban centers of Pawtucket and Central Falls between 1970 and 1975. Other communities showing decreases include Grafton, Blackstone and Millville. Although the other communities showed increases ranging from 1.1 to 8.3 percent, these increases were not sufficient to offset an overall loss of population of 2.5 percent for the impact communities. The population densities in 1975 ranged from 151 in Sutton to 13,907 in Central Falls and are displayed in Table 1-7.

Major Skills and Occupations - Occupation data for the impact area (see Table 1-8) shows a considerable proportion of blue-collar jobs (operatives, craftsmen, and foremen) in the labor force. The older central cities in the impact area, including Pawtucket and Central Falls, have a substantial percentage of labor-intensive industries. This reflects the historical dependency on textiles which characterizes the northeast part of the country. Thus, a considerable proportion of the labor force is employed in blue-collar and related office support jobs. Close to 30 percent of the employed in impact area communities were in the operatives category. None of the communities had less than 23 percent of its workers in this category; Central Falls had the highest proportion with 42.4 percent employed in the operatives group. The next largest group in the impact area communities are clerical workers, making up 17.2 percent of the employed, followed closely by 15.5 percent employed in the craftsmen/foremen group. These three groups, operatives, clerical, craftsmen/foremen combine to compose over 60 percent of employed workers.

Examination of the commuting characteristics of the Blackstone Valley's residents shows that of the cities and towns within the watershed in the Providence metropolitan area, 80 percent work within the PPW SMSA. Of those, over 40 percent work in the city of Providence and another 31 percent work in the "inner ring" of the remainder of Providence County, indicating the

TABLE 1-8

Percent Distribution of Total Employed Workers by Occupation for the Impact Area

	Total	Pnt. Tech.	Mngrs. Prop.	Clerical	Sales	Craftsmen Foremen	Oper.	Service	Labor	Pvt Hsehld
Millbury	4978	11.0	8.1	19.7	4.3	16.5	25.2	11.4	3.4	0.4
Sutton	1861	11.5	6.3	15.9	4.4	19.2	27.4	10.3	4.7	0.3
Grafton	4513	14.2	7.8	14.8	7.4	16.1	22.3	11.5	5.0	0.7
Northbridge	4632	10.6	5.2	17.7	3.4	17.7	29.6	11.4	4.0	0.4
Uxbridge	3481	9.5	6.0	16.0	4.0	17.0	29.0	11.3	6.6	0.6
Millville	N.A									
Blackstone	2482	10.1	3.3	12.2	5.0	19.1	33.1	11.6	4.8	0.8
Cumberland	11569	12.7	9.1	16.9	5.9	16.1	26.0	9.1	3.7	0.5
Lincoln	6870	12.0	10.0	19.7	7.5	15.5	23.0	8.3	3.7	0.3
Central Falls	7549	6.0	3.5	13.3	4.8	13.4	42.4	11.5	4.8	0.2
Pawtucket	33124	10.1	5.8	18.0	6.2	14.6	31.1	9.9	4.0	0.3
TOTAL	81059	8542	5321	13918	4659	12579	24070	8270	3404	296
		10.5	6.6	17.2	5.7	15.5	29.7	10.2	4.2	0.4

strength of Pawtucket, Central Falls, East Providence and North Providence as employment centers. The Providence County "outer ring" also exhibits a very significant pull as a work trip destination (18 percent), especially due to Woonsocket and Cumberland as employment centers.

The Worcester metropolitan area shows a similar split of persons working inside (80 percent) and outside its SMSA, but it exhibits a stronger centralization of work trip destinations with almost 80 percent of those working inside the SMSA working in the city of Worcester itself. The towns surrounding Worcester that are within the watershed, Auburn, Millbury, Grafton, and Shrewsbury, do show a much stronger pull for the remaining work trips (12.5 percent) than the surrounding towns to the north which are outside the watershed (2.4 percent).

TABLE 1-6
POPULATION CHANGES, 1960-1975
CITIES AND TOWNS OF THE BLACKSTONE VALLEY

City/Town*	1960	1970	(Over 1960) Percent Change	1975	(Over 1970) Percent Change
Massachusetts					
Shrewsbury	16,623	19,196	+15.5	21,965	14.4
MILLBURY	9,623	11,987	+24.6	12,121	1.1
Auburn	14,047	15,347	+9.3	15,626	1.8
GRAFTON	10,621	11,659	+9.7	10,630	-8.8
Upton	3,127	3,484	+11.4	3,777	8.4
NORTHBRIDGE	10,800	11,795	+9.2	12,165	3.1
Hopedale	3,987	4,292	+7.6	4,014	-6.5
UXBRIDGE	7,789	8,253	+5.9	8,528	3.3
Douglas	2,559	2,947	+15.2	3,174	7.7
BLACKSTONE	5,130	6,565	+28.0	6,486	-1.2
MILLVILLE	1,567	1,764	+12.6	1,744	-1.1
SUTTON	3,638	4,590	+26.2	4,969	8.3
Mendon	2,068	2,524	+22.0	2,714	7.5
Bellingham	6,774	13,967	+106.0	14,461	3.5
Rhode Island					
Woonsocket	47,080	46,820	-0.6	46,888	0.1
N. Smithfield	7,632	9,349	+22.5	10,354	10.7
Burrillville	9,119	10,087	+10.6	11,483	13.8
Glocester	3,397	5,160	+51.9	6,353	23.1
Smithfield	9,442	13,468	+42.6	14,283	6.1
LINCOLN	13,551	16,182	+19.4	17,177	6.1
CUMBERLAND	18,792	26,605	+41.6	27,648	3.9
CENTRAL FALLS	19,858	18,716	-5.8	16,689	-10.8
PAWTUCKET	81,001	76,984	-5.0	72,024	-6.4

Source: "Southeastern New England Study of Water and Related Land Resources," New England River Basins Commission, Interim Report, 1973 and County and City Data Book, 1977, U.S. Department of Commerce, U.S. Bureau of the Census.

*The following cities and towns are not included because they do not lie significantly within the Blackstone River Drainage Basin, nor are their economies significantly related to the rivers that make up that drainage basin: Oxford, Leicester, Paxton, Holden, Boylston, Hopkinton, Milford, Franklin, Wrentham, Plainville, North Attleboro, Attleboro, Massachusetts.

NOTE: Impact area communities are indicated by upper case lettering

TABLE 1-7

POPULATION DENSITY*
STUDY AREA COMMUNITIES

	Land Area (Sq.Mi.)	1960	1970	1975
Millbury	16.0	601	749	757
Sutton	32.7	111	140	151
Grafton	22.8	466	511	466
Northbridge	17.2	628	686	707
Uxbridge	29.5	264	280	289
Millville	4.9	320	360	355
Blackstone	11.2	458	586	579
Cumberland	27.1	693	982	1,020
Lincoln	18.6	729	870	923
Central Falls	1.2	16,548	15,596	13,907
Pawtucket	8.8	9,205	8,748	8,184

Source: "Southeastern New England Study Water and Related Land Resources," New England River Basins Commission, Interim Report, 1973 and County and City Data Book, 1977. U.S. Dept of Commerce, U.S. Bureau of the Census.

*Persons per square mile

Income and Education Levels - Median income for the study area communities ranged from $7,778 in Central Falls to $11,811 in Grafton. This compares to $9,929 and $10,088 in the PPW and Worcester SMSA's respectively. Income data for all impact area communities is displayed in Table 1-9 with median number of school years completed. As indicated in the table, the median income and the percent earning over $15,000 are significantly greater in suburbanized towns, (Grafton and Cumberland) than in the central cities.

Housing - Table 1-10, Housing Characteristics - Cities and Towns of the Blackstone Valley, again points out the characteristic demographic changes of the '60's. Significant growth in single family houses in the suburban communities is observed along with a decline in the number of housing units in the higher density urban areas with primarily multifamily housing.

The degree of recent housing construction activity is shown in Table 1-11 Residential Building Permits Issued - 1972, 1973. It is interesting to note that even though population is declining in the older core cities of Providence, Pawtucket, Central Falls, Woonsocket and Worcester, there is still evidence of housing construction, mostly multifamily, which is replacing much of the housing demolished for urban renewal, condemnation, or for some higher order purpose. The close in suburban communities such as Shrewsbury, Auburn, Grafton, Cumberland, and Lincoln show signs of higher density development with a significant percentage of new housing starts in multifamily units.

Providence, Pawtucket, Central Falls and Woonsocket in Rhode Island and only Worcester in the Massachusetts portion of the basin have undergone varying types and degrees of Federal and State aided urban renewal. The prime investment has been in reviving the areas in and around the urban cores.

Available housing data for impact area communities (see Table 1-12) reveals a greater preponderance of multifamily units in the larger cities and higher median values for owner-occupied units in the emerging suburbs, particularly Cumberland and Lincoln where demand for residential accommodations has been fairly intense. In all of the impact towns and cities, vacancy rates (especially for owner-occupied units) are rather low and normal residential development activities have been adversely affected by a recession in the housing industry.

TABLE 1-9

Income and Education Levels for Study Area Communities 1970

	School Years Completed	% Incomes Under $4,000	% Incomes Over $15,000	Median Income
Millbury	11.7	7.0	17.6	$ 9,731
Sutton	12.1	4.8	20.2	$10,538
Grafton	12.1	5.5	25.5	$11,711
Northbridge	10.8	9.7	14.4	$ 8,807
Uxbridge	11.2	11.2	17.9	$ 9,632
Millville	N.A.			
Blackstone	10.4	11.2	12.6	$ 8,457
Cumberland	11.7	6.1	25.2	$11,311
Lincoln	11.7	9.7	22.0	$10,501
Central Falls	9.0	19.9	7.0	$ 7,778
Pawtucket	10.6	14.0	14.3	$ 9,265
Worcester SMSA	12.1	11.4	20.5	$10,038
PPW SMSA	11.5	11.9	19.3	$ 9,929

TABLE I-10

HOUSING CHARACTERISTICS
CITIES AND TOWNS OF THE BLACKSTONE VALLEY

				Housing Characteristics, 1970			
	Number of Housing Units			Percent Single	Percent Built	Median Value	Full Value Tax Rate
City/Town*	1960	1970	% Change	Family	Since 1950	S.F. House	1971
Worcester	58,986	58,569	-0.7	34	18	$17,900	$85.80
Shrewsbury	4,922	5,824	18.3	83	53	20,700	40.50
Millbury	2,982	3,667	23.0	66	40	18,300	52.00
Auburn	4,057	4,539	11.9	82	50	18,400	41.00
Grafton	2,683	3,181	18.6	65	39	19,200	40.50
Upton	1,010	1,106	9.5	65	37	17,400	52.60
Northbridge	2,299	3,745	62.9	42	25	17,600	48.60
Hopedale	na	1,300	-	56	24	19,100	45.40
Uxbridge	na	2,632	-	59	27	16,600	45.20
Douglas	na	984	-	65	25	16,300	46.00
Blackstone	1,534	1,958	27.6	56	32	16,000	58.40
Millville	493	533	8.1	-	-	12,500	62.00
Sutton	1,161	1,421	22.4	74	45	18,000	52.80
Mendon	na	827	-	76	38	16,700	39.90
Bellingham	2,027	3,653	80.2	85	69	19,100	30.60
Woonsocket	16,269	16,481	1.3	23	18	16,400	36.73
Central Falls	7,249	6,847	-2.5	8	6	13,800	36.08
Pawtucket	28,130	27,859	-0.1	33	19	16,400	31.20
North Smithfield	2,285	2,806	22.8	76	46	18,900	24.06
Cumberland	5,697	7,846	37.7	72	56	20,700	22.93
Lincoln	4,283	5,212	21.7	54	36	20,700	24.44
Smithfield	2,763	3,817	38.1	81	52	19,200	26.01
Glocester	na	1,620	-	85	47	17,200	18.38
Burrillville	na	3,045	-	54	26	14,900	26.76
Providence	73,027	68,132	-6.8	22	12	16,800	33.96

na = not available

Sources: U.S. Census, "Detailed Housing Characteristics", Mass. and R. I.; "Annual State Report on Local Government Finances and Tax Equalization", R. I. Department of Community Affairs, 1973; "1971 Tax Rates", Massachusetts Taxpayers Foundation, Inc.

* The following cities and towns are not included because they do not lie significantly within the Blackstone River Drainage Basin, nor are their economies significantly related to the rivers that make up that drainage basin: Oxford, Leicester, Paxton, Holden, Boylston, Hopkinton, Milford, Franklin, Wrentham, Plainville, North Attleboro, Attleboro, and Seekonk, Massachusetts; and East Providence, Rhode Island.

TABLE 1-11

RESIDENTIAL BUILDING PERMITS ISSUED - 1972, 1973
CITIES AND TOWNS OF THE BLACKSTONE VALLEY

City/Town*	1973 # of Buildings	1973 # Fam. Accom.	1972 # of Buildings	1972 # Fam. Accom.	Total # of Buildings	Total # Fam. Accom.
Worcester	149	1,111	253	2,111	402	3,222
Shrewsbury	99	229	78	284	177	513
Millbury	44	52	58	134	102	186
Auburn	74	139	55	55	129	194
Grafton	45	127	30	43	75	170
Upton	31	29	21	21	52	50
Northbridge	56	56	59	59	115	115
Hopedale	na	na	na	na	na	na
Uxbridge	47	93	31	31	78	124
Douglas	26	23	28	30	54	53
Blackstone	24	24	23	73	47	97
Millville	4	4	6	6	10	10
Sutton	47	48	38	39	85	87
Mendon	11	11	na	na	na	na
Bellingham	76	92	87	88	163	180
Woonsocket	62	298	89	487	151	785
Central Falls	3	13	3	3	6	16
Pawtucket	63	158	75	169	138	327
North Smithfield	87	92	69	82	156	174
Cumberland	97	104	107	119	204	223
Lincoln	75	131	71	76	146	207
Smithfield	103	118	86	140	189	258
Glocester	83	83	75	80	158	163
Burrillville	95	98	67	67	162	165
Providence	147	506	195	1,124	342	1,630

na = not available

*The following cities and towns are not included because they do not lie significantly within the Blackstone River Drainage Basin, nor are their economies significantly related to the rivers that make up that drainage basin: Oxford, Leicester, Paxton, Holden, Boylston, Hopkinton, Milford, Franklin, Wrentham, Plainville, North Attleboro, Attleboro, and Seekonk, Massachusetts; and East Providence, Rhode Island.

TABLE 1-12

HOUSING CHARACTERISTICS FOR IMPACT AREA COMMUNITIES

	Total Year Round Housing Units						
	% single	% multi	% mobile	total #	% Owner occupied	Median value	Money rate
Millbury	67.3	32.6	0.1	3,634	69.6	$18,200	
Sutton	75.0	24.7	0.3	1,419	74.0	$19,600	
Grafton	64.9	34.7	0.4	3,186	68.5		
Northbridge	40.8	59.1	0.1	3,744	51.1		
Uxbridge	57.1	42.1	0.8	2,629	62.7	$16,400	0.2
Millville				533	72.0	$12,500	
Blackstone	56.8	42.8	0.4	1,977	64.2	$15,800	0.6
Cumberland	72.0	27.6	0.4	7,839	75.6	$20,600	0.3
Lincoln	56.9	42.7	0.4	5,211	64.7	$20,700	0.5
Central Falls	8.1	91.9	--	6,847	24.6	$13,500	0.5
Pawtucket	33.8	65.5	0.6	27,857	46.2	$16,400	0.4

Source: 1970 U.S. Census of Housing

DEVELOPMENT AND ECONOMY

Historical and Cultural Development - The Blackstone River was named for the first white settler on its banks, William Blackstone. An Episcopal clergyman, he left Boston in 1634 to find solitude and to get away from the customs and methods of the Puritans with whom he disagreed. He established a home in what is now Lonsdale, about two miles northwest of Pawtucket. Blackstone was also the first permanent settler in Boston, with a concession or grant of more than 800 acres that included the present Boston Common.

Between Valley Falls and Pawtucket Falls, a distance of about two miles by river, there is a fall of about 25 feet where, in the old days the river boiled over one rock ledge after another. It was at the lower end of the falls that the first development on the river was constructed by Joseph Jenks, Jr. Jenks came to Rhode Island in 1669 from Lynn, Massachusetts, where his father operated the first iron foundry in America. Attracted by the water power potential, Jenks purchased 60 acres of land near the Pawtucket Falls in 1671 and established a forge, sawmill and carpenter shop on the west bank below the present Main Street bridge. At the foot of the falls he erected a waterwheel to turn the mill. His skill as a maker of tools and his success in harnessing the river impressed other pioneers, and gradually a small settlement was formed near the forge and mill. As other portions of the basin became settled, the available water power in the river was developed; and by 1700 many grist and sawmills were in operation.

It was in Pawtucket that the cotton manufacturing industry in America had its start. In January 1790, the firm of Almy and Brown was attempting to spin cotton commercially. It secured the services of Samuel Slater, an Englishman well versed in the cotton spinning processes then being employed in England. At that time, exportation from England of Arkwright machinery, or any models or designs thereof, was prohibited by English law. The equipment at hand proved unsatisfactory so Slater proceeded to design and construct Arkwright type spinning machines from memory. The first plant, completed in December 1790, consisted of three cards, drawing and roving frames and two spinning frames. The plant was located at the southwest end of the bridge over the falls, and the fast flowing river was used to power the machines.

Slater's machines proved so successful that the company soon had surplus yarn on hand and had to suspend operation for several months. At that time, all weaving was done on hand looms and the

yarn produced could not be converted into cloth as rapidly as it is today. When operations resumed, Slater and his associates decided to build a new plant, and in 1793 they completed construction of the first real cotton mill in America. Now known as "Old Slater Mill," it stands on the west bank of the river in Pawtucket.

Following this start, the textile industry soon spread throughout the basin and used the river as a source of power. Slater played a very important part in this expansion. Around 1798 he erected a second mill on the east side of the river in what was then part of the town of Rehoboth, Massachusetts, but is now Pawtucket. In 1811, he founded a cotton and woolen mill on the Merrimack River in Amoskeag Falls, later the industrial city of Manchester, New Hampshire.

Industrial development in the basin required improved transportation of goods and passengers between ocean and inland points. In 1796 John Brown and several associates considered the possibility of a canal from Providence to Worcester, by way of the Blackstone River. The route was surveyed and a plan formulated that was considered to be practical and easy to execute. The Rhode Island Legislature voted the company ample power, but Massachusetts withheld assent and the project came to a premature end.

In about 1822 a group of Providence and Worcester people interested in the extension of water transportation to Worcester employed Benjamin Wright, who had been an engineer on the Erie Canal, to report on the Blackstone Canal Project. However, since 1796 when the project was first considered, many manufacturing establishments had secured and were utilizing mill privileges along the river. This added considerably to the value of the land required for the canal. Notwithstanding, the project was recommended for construction at a cost of $323,319 for labor, based on an average monthly wage of $10 to $12. The proposed canal was to be 45 miles long, starting at Thames Street in Worcester, near the present courthouse, continuing down the valley of the Blackstone River to Scott Pond in Lincoln, just above Central Falls, and thence down the Moshassuck River to tidewater at Providence; a total fall of 451.61 feet at 62 locks.

The canal was finally constructed between 1826 and 1828 by the Blackstone Canal Company at a total cost of $750,000. As constructed, it contained 48 locks, had a depth of 4 feet and top and bottom widths of 34 and 18 feet, respectively. Operation of the canal, however, was not a financial success. At times a deficiency in water supply existed and at other times injurious

floods caused damage. In the winter months, it was out of service because of ice. In 1848, soon after the completion of the first railroad between Providence and Worcester, the canal was abandoned. Although it was not a success as a transportation project, it left the water power situation of the river in a better condition. The various ponds formed on the upper reaches of the river by the canal dams provided a more constant and better controlled supply of water for downstream industries dependent on the river for power. Little visible evidence of the canal remains today.

The advent of steam power, the opening of the canal and, finally, the construction of rail facilities all gave impetus to the expansion of industry, the consequent growth of towns along the river and the development of new communities along its tributaries. Worcester became the greatest industrial city in the United States not located on a major waterway -- a leader in the manufacture of wire, textiles, grinding wheels, machinery and other products. Late in the 1800's many of the industrial plants in the basin and elsewhere began to convert from mechanical to hydroelectric power. Utilization of available hydro sites in the basin reached a peak shortly after the turn of the century.

The Blackstone River has thus played a very important role in the industrial history of New England and the United States. Although many of its earlier developments have been abandoned, it will continue to be important to the economic welfare of the industrial communities along its banks.

Economic Development - In colonial days the Blackstone Valley was a region of subsistence farming. Sheep farming for wool, bog iron mining and forestry, and corresponding industries to process the local resources or to satisfy local demand were the residents principal occupations. The Blackstone Valley gradually became a processor of imported materials, primarily for reexport to other parts of the United States and the world--in essence, a natural resources based economy shifted to a human skills based economy. The first part of this shift, agriculture and mining to manufacturing, occurred between the American Revolutions elimination of the British ban on manufacturing in the Colonies and the Homestead Act's explosive opening of the more fertile and hence more competitive western agricultural lands. Higher wage opportunities of manufacturing and lower Midwestern farm prices contributed to the decline of agriculture in the region.

The second part of the shift, from manufacturing processes using local materials to those using imported materials, has extended from the early 19th century to the present day because of

the early depletion and general lack of local raw materials.

Concurrent with the shift to importing materials and exporting products, there has been a trend toward increasing labor intensification and reducing use of materials to offset and minimize shipping costs and decrease the cost of the regions products. The result has been increasing specialization in the manufacture of such products as machinery and electronic equipment.

Over the past few decades, the national economy has become increasingly service-oriented as goods-producing industries have been deemphasized. On a national level, manufacturing employment grew by only 27 percent between 1950 and 1970 whereas employment in service-related industries increased by 88 percent during the same time. From 1960 to 1970, the growth rates were 15 and 43 percent respectively. According to a report entitled "Tomorrow's Manpower Needs," published by the U.S. Department of Labor in 1971, such a service-oriented economy is expected to continue.

While the national economy has been changing direction, that of the Blackstone Valley has remained strongly in the manufacturing sector. Although the service sector is beginning to gain some importance, in 1969 manufacturing still accounted for 93 percent of the economic base in the Worcester-Fitchburg-Leominster area and for 87 percent in the Providence-Pawtucket-Warwick area. (The economic base is comprised of those industries which sell goods or services to consumers outside the region.)

The Blackstone Valley area, Providence to Worcester, is significantly more manufacturing based than the national average, while the Boston area to the northeast is somewhat less so. Although manufacturing jobs accounted for more than a third of total employment in 1970 in the Worcester and PPW SMSA's (see Table 1-15) practically every city and town within the Blackstone watershed has been losing manufacturing employers. Part of the current decline in manufacturing employment is attributable to the slow growth that is occurring in the nation as a whole (only 15 percent increase between 1960 and 1970). The more dominant factor, however, has been the exodus of manufacturing establishments. Accessibility to rail and water transport that once attracted many industries to new England is no longer such an important criteria. Trucking, for many firms, is now the major mode of transport and access to high speed roads can be found in every region of the country. This, together with lower tax and wage rates found in other areas, has caused a major movement of industries out of the Blackstone Valley as well as the entire New England region.

The Blackstone River Basin's economy is now primarily based on manufacturing jewelry, electrical and other machinery, and fabricated and primary metals. Other significant products are textiles, food products, printing and publishing, and chemicals. Manufacturing employs about 37 percent of the region's total workers, agriculture and mining about 2 percent, trade about 7 percent, and services (including financial, business, medical, and educational) about 19 percent. The remaining 36 percent is split between construction, transportation, utilities, government and miscellaneous retail trade.

The prominence of manufacturing continues to be reflected by employment data for the study area communities. With the exception of Blackstone, manufacturing accounted for over 40 percent of employment opportunities in each of the impact area communities. Generally, the wholesale and retail trade sector followed manufacturing in importance, followed by the services sector. Table 1-15 provides employment data for each industrial sector in each community. Nineteen-sixty seven data are also presented and the percent change to more recent data is indicated.

Economic Trends - The Blackstone River Basin's economy is now primarily based on manufacturing jewelry, electrical and other machinery and fabricated and primary metals. Other significant products are textiles, food products, printing and publishing and chemicals. Manufacturing employs about 37 percent of the regions total workers, agriculture and mining about 1 percent, trade about 7 percent and services (including financial, business, medical and educational) about 19 percent. The remaining 36 percent is split between construction, transportation, utilities, government and miscellaneous retail trade.

In a larger southeastern New England regional context, the Blackstone Valley is part of a manufacturing hinterland that surrounds the Boston SMSA and is dependent on Boston for specialized banking, medical and educational services. This relationship is evidenced by Boston's low employment rate of 22 percent in manufacturing and high employment rate of 27 percent in services.

In recent trends in economic activity within this region (1963 to 1967), the greatest gains have been registered in the metals industries, with constant dollar value added increases of 87 percent in jewelry, silverware and plated ware, 54 percent in primary metals, 49 percent in machinery, 31 percent in fabricated metals, 27 percent in instruments and 27 percent in electrical equipment. Other increases included 48 percent in paper products, 34 percent in printing and 27 percent in stone, clay and glass

products. Textiles, in the same period, continued their long term decline. Some concentrations of these industries are on the valley's fringes--Providence and Attleboro for example--but they should still have significant impact on the future employment of the valley's residents.

Land Land Use Characteristics - Development in the Blackstone River watershed is generally concentrated in several large urban centers and in a number of small rural communities. Nearly all evolved in response to industrial land users locating at or near water power sources (the Blackstone and its tributaries) and/or available transportation facilities (the Blackstone Canal, the Providence and Worcester Railroad and the area's primary roads).

The major urban centers -- Providence-Pawtucket-Central Falls, Woonsocket and Worcester -- are the basin's oldest principal settlements. While once sources of considerable economic vitality (especially during the 18th and 19th centuries), these urban centers have, in more recent years, lost population and industry to more attractive areas within their respective suburban rings. Other centers of urban activity -- chiefly small mill towns -- are scattered throughout the watershed along various stream valleys and rural roads, leaving large areas of open space or lands developed at very modest rural densities, particularly in the middle and western sectors of the basin.

Of the cities and towns within the flood plain only Pawtucket, Central Falls and Woonsocket are fully developed. In the town of Cumberland, Rhode Island, existing development (mostly residential) is located along Mendon and Diamond Hill Roads, intensifying in the Lonsdale and Valley Falls communities and leaving large open spaces in the north and central sections of the town. The other towns in the Rhode Island portion of the impact area--Lincoln, North Smithfield and Burrillville--are less developed and are experiencing fewer growth pressures.

In the Massachusetts portion of the impact area, existing development closely follows State Route 122 and the Providence and Worcester Railroad. A comparatively intense stretch of development for an area essentially rural in character lies between Uxbridge Center and Whitinsville and runs along the Mumford River between the towns of Uxbridge and Northbridge. Most other lands in this portion of the impact area either remain as open space or have been developed at rural densities.

Most development in the primary impact area (defined as the flood plain associated with the design flood and the areas to be flooded by possible reservoir construction) is concentrated in the

lower reaches of the Blackstone amidst the heavily developed areas of Pawtucket, Central Falls and their suburbs. In Pawtucket and Central Falls nearly all of the Blackstone's available flood plain has been fully developed, primarily by industrial and commercial users. Immediately upstream of this area are some 150 to 200 acres of undisturbed marshland (the Valley Marshes), but the Blackstone again loses most of its flood plain near the Lonsdale section of Cumberland--in this instance to a variety of commercial, industrial, residential and transportation uses.

Above Pratt Dam in Lonsdale and on to Woonsocket most of the available flood plain is vacant. However, three industrial complexes are located along this stretch: the Berkeley Industrial Park at Martin Street, of which some 65 acres (including 5 industrial plants, a ball field and some vacant land) are located immediately within the flood plain; the Owens-Corning Fiberglass Company at Ashton; and the Berkshire-Hathaway Mill Complex at Albion.

Within the remaining flood plains of the main stem, the only significant concentration of development is in Millville, Massachusetts, where the Loumac Combing Company and a number of single family residences along State Route 122 are subject to recurring flood damages. Below this stretch, the flood plain is fairly narrow and, in Woonsocket, previous channel improvement and local protection projects have withdrawn nearly all of the natural flood plain from potential project impact. Above Millville there is a significant amount of vacant flood plain that includes a considerable amount of marshlands unsuitable for development.

Along the tributaries extending out to the State's proposed Nipmuc Water Supply Reservoir, existing flood plains are fairly narrow. Along the Branch River, which has been dammed to create the Slatersville Reservoir, most of the available flood plains are vacant, though in several cases they have been developed by industrial and, to a lesser extent, residential users. The flood plains of the Pascoag and Nipmuc Rivers remain generally unencumbered. Near the Nipmuc, however, residences have been built along Round Top Road and, to a lesser extent, Brook and Sherman Roads.

In its lower reaches, the Mumford River flows through a corridor of development concentrated at Whitinsville, North Uxbridge and Uxbridge Center. Along this stretch the river is straddled by a major industrial complex at Whitinsville and by Emile Bernat & Sons, a textile plant in Uxbridge Center. The only appreciable flood plain area here is located just above Carrons Pond and, with the exception of several single family houses, is

largely undisturbed.

Recreation - Public recreation lands in the Blackstone River Basin, including State and local parks, State forests and management areas, town forests, conservation commission lands and private camps and recreation areas, total 21,179 acres or approximately 7 percent of the basins land resources. More than half of this land is State owned.*

Very little of this recreational acreage is along the Blackstone River, which is still of poor quality although it is considered suitable for canoeing as far south as Woonsocket. There are no sizable recreation facilities within the area affected by the Corps flood protection projects addressed in this report, although there are several small parks and proposed conservation areas. In addition, the Sayles Finishing Company has donated a 100-150 acre parcel to the State of Rhode Island for conservation and relocation. This land includes valley marshes and some flood plain land along the Lincoln side of the Blackstone.

Nipmuc Reservoir - The considered State Nipmuc Water Supply Reservoir project is located within a sparsely settled wooded rural area that has one public recreation facility, the Round Top fishing area. The stream is annually stocked with trout and is highly esteemed locally.

Berkeley Area, Cumberland, Rhode Island - There is one recreation facility in the immediate impact area, the city owned Berkeley Oval located just south of Martin Street. This 8-acre site contains a ball field, a well station and pumping facility. The facility appears to be fairly important to the adjacent community (Cumberland Planning Districts 58 and 63) since it is the only recreational resource now available in a moderately growing area that has projected recreation needs of 21 acres by 1980.*

In addition, the Cumberland Conservation Commission has recommended that a strip of land extending the length of the Blackstone River be conserved to prevent further pollution of the

*The Outdoor Recreation Planning Group, Preliminary Single-Purpose Plan Report: Outdoor Recreation (New England River Basins Commission: September 7, 1973, p.1.)

*Rhode Island Development Council, Cumberland Comprehensive Community Plan, October 1966, p.58

Blackstone River.** The total land area to be preserved would be approximately 20 acres, with the minimum width of the strip being 300 feet. Recreation uses contemplated include hiking trails, scenic sites for viewing the waterfalls and picnicking. It is hoped that conservation easements rather than outright acquisition can be used.

Transportation Facilities - The Blackstone Valley is served by all types of transportation. Rail service by the Providence and Worcester Railroad connects the basin with Conrail and Amtrak at Providence. Bulk freight service is provided by main and branch lines of Conrail while fast and regular passenger service to Boston, New York and Washington is furnished by Amtrak.

A number of major highways run through the northern and southern parts of the basin. Route 146 connects I-90 near Worcester with I-296 and I-95 by Providence-Pawtucket. These intersect I-195, I-495 and U.S. 6 and link the basin with the metropolitan areas of Hartford, New York and Boston. This arterial network provides excellent transportation for the trucking firms and interstate bus companies located in this area.

Air transportation is provided at the Worcester Municipal Airport in Worcester, Massachusetts, the Theodore Francis Greene State Airport in Warwick, Rhode Island and the North Central State Airport in Smithfield, Rhode Island, about 7 miles northwest of Providence. Most of the waterborne commerce needs of the basin are served by the Port of Providence, which has a 40-foot deep main ship channel.

**Ibid, p.68

FLOOD PROBLEMS

AND

FLOOD MANAGEMENT NEEDS

This section describes the problems and needs of the basin, their magnitude, the status of existing plans and improvements desired by local interests. It also presents hydrologic, hydraulic, flood and economic analyses of the study area.

FLOOD PROBLEMS

Consistent with the objectives of the Urban Study Program, the Blackstone River Basin study has employed a comprehensive approach to the area's problems and needs. A preliminary assessment of problems has been made using data from completed or ongoing studies supplemented by information received at public and informal meetings and from written communications. Identifiable water resources problems, as they relate to existing and projected conditions, are detailed in the following paragraphs.

The study area has experienced riverine flooding. A primary reason for this occurrence is the area's geographical location. It is exposed to three general types of storms, each having its own characteristics. Coastal storms normally generate high winds and heavy seas, occasionally causing tidal flooding of coastal and estuarine structures. Continental storms generally borne by the prevailing westerlies or localized storms can cause heavy precipitation and bring about riverine flooding. The area is also vulnerable to hurricanes of tropic origin, normally accompanied by heavy rainfall which can cause severe riverine and tidal flooding.

Flooding upstream of the Main Street Dam in the city of Pawtucket is strictly riverine. Located directly in the corridor of the northeastern United States megalopolis, this region has sustained traumatic physical land changes primarily caused by an expanding economy, urbanization and an improved highway system.

The evolvement of these changes has resulted in increased use of the flood plains. One reason associated with this trend is the fact that easily accessible flood plains are the most economical areas to develop since other available land at nominal cost is rather scarce. Consequently, random commercial and industrial growth has tended to expand into undeveloped areas at the expense of the flood plains. The improved highway system, by providing easy access to the flood plains, has been a principal perpetrator

of this development. In fact, land near or adjacent to the transportation system has been very vulnerable to land speculators.

Rural communities once located far from densely populated areas are gradually falling prey to the same expansion pressures as their urban neighbors and are becoming bedroom communities with many amenities for urban workers. Manufacturing and distribution firms seeking less crowded environs are following the same pattern. Sparsely populated forests and isolated flood plains in the suburban and rural communities are beginning to succumb to the urban sprawl.

As this urbanization trend continues uncontrolled, the present flood problems in the more densely populated areas will not only increase at a higher rate, but heavy losses exceeding earlier events can be expected in some communities.

Present flood problems in this study area are concentrated in the more densely urbanized areas and generally decrease in magnitude in the suburban communities. In rural areas the flood problems are few and of inconsequential value. Most of the existing flood problems have been directly associated with loss of natural valley storage by flood plain encroachment; a lack or nonenforcement of zoning ordinances; dam failures or a lack of periodic maintenance; inadequate channel capacity and a lackadaisical river channel maintenance.

With the present trend of uncontrolled growth in flood prone areas, numerous localities will be subjected to even greater flood losses from recurring storms. The 1968 flood accelerated and expanded both Congressional and local interest in solving these extensive flooding problems in the Blackstone. As a result, the Corps of Engineers has continued its effort to develop a balanced flood plain management program that would afford flood relief to areas subjected to continuing flood damages while also providing for other multipurpose benefits such as water supply, recreation and low flow augmentation.

The Corps of Engineers investigated several flood protection actions in the Blackstone River watershed based upon the recommendations of preliminary studies conducted in 1974 by a consulting engineering firm. The problem areas investigated included the Berkeley and Ashton sections of Cumberland, Rhode Island, a location in Uxbridge, Massachusetts and various sites in Pawtucket, Rhode Island.

The communities which had flooding problems are as follows:

Millbury, Massachuseetts - Damage was primarily received by industrial and railroad properties in Millbury, with smaller amounts of highway and urban damage.

In this reach, from Route 146 to the railroad bridge just downstream of Water Street, most of the urban industrial damage occurred in the industrial areas along River Street, West Street and Water Street.

Much of the railroad damage along with some urban residential undoubtedly occurred from the railroad bridge to South Main Street.

In the reach from South Main Street to the former Hayward-Schuster Dam, urban residential and commercial damage occurred.

Most of the damage in Millbury from the former Hayward-Schuster Dam downstream to Cross Street was received by industry and highways.

Sutton - The major damage in Sutton occurred at a chemical firm on Follett Street.

Grafton - Only a small amount of industrial and highway damage occurred from Follett Street to the Saundersville Dam reach.

Nearly all of the damage in Grafton was incurred from the Fisher Dam downstream to Depot Street, including the washout of Main Street (Rte. 122A) and Depot Street. The Fisherville Mfg. Co. just south of the dam was not extensively damaged; however, reports indicate that the urban industrial area near it (at Main & Cross Streets) would have been extensively damaged by flood stages slightly higher than the 1955 flood crest.

Northbridge - This community incurred the largest total losses of any town on the Blackstone between Worcester and Woonsocket in the 1955 flood.

In the reach from the Grafton-Northbridge town line to the former Paul Whitin Mfg. Co. Dam in Rockdale, there is some urban residential and industrial property.

The Whitin Mill at the dam site incurred heavy damages even though it was not in operation at the time. Recurring losses to the Coz Chemical Co., now occupying the building, would be much higher. In total, the Rockdale section around the mill suffered over $500,000 damage in 1955, approximately two-thirds of which

was commercial-residential.

From the former Paul Whitin Dam to the Kupfer Mill Dam at Riverdale Street, the largest single loss in Northbridge (over $200,000) occurred. The Kupfer Mill Dam itself washed out in the 1955 flood but has been replaced by a gated dam structure.

Uxbridge - The majority of damage in Uxbridge was in the industrial and highway categories. The Rice City Pond Dam washed out in the 1955 flood and was replaced by the State with a dam having a crest approximately 3 feet lower than the original dam. Most of the industrial damage occurred at the Stanley Woolen Mill just above Mendon Street. A small amount of urban damage was recorded along Main Street and at the intersection of River and South Streets, in both instances at the outer limits of the flood plain.

Another major flood problem is one of the general overflow of the Mumford River into the other industrial area of Uxbridge. Flooding on this river was caused principally by backwater from the Blackstone River. The high water marks listed were taken at the shipping platform of the Emile Bernat and Sons Company:

DATE	FLOOD ELEVATION	ABOVE GROUND FLOOR
4 Nov 1927	226.4	10"
19 Mar 1936	226.8	1' - 2"
19 Aug 1955	231.5	5' - 11"

Millville - A large amount of industrial and some urban residential damage occurred in the area just south of Central Street along Route 122 around the Loumac Combing Company. This area reportedly suffered the largest concentration of damage (over $1 million in total costs) on the Blackstone north of Woonsocket in 1955. An industrial complex and a number of residences were affected.

Blackstone - Nearly all of Blackstone's damages were received by rail and highway facilities.

Cumberland - Lincoln - Cumberland damage was largely industrial and commercial-residential (urban). Damage in Lincoln was mostly industrial. The area hardest hit in 1955 was the Lonsdale section from just above the Pratt Dam to just above John Street.

From the Ashton Fiberglas Dam south through the industrial area south of Martin Street, there is a prime concentration of new industrial activity in the flood plain. There are five industrial plants in this reach, three of which have been built since 1955. Recurring damages to the Owens-Corning Fiberglas Co. amount to over $900,000 at current price levels and recurring damages to the other four industries at the foot of Martin Street amount to over $2 million. The Lonsdale Drive-In Theater is in a flood prone area. The Lonsdale portion of this reach from just above the Pratt Dam to just above John Street was the most severely damaged in 1955. There was over $800,000 damage on the Cumberland side and $540,000 damage to two industrial plants on the Lincoln side.

The Pawtucket-Blackstone Chamber of Commerce submitted a brief through proper channels supporting an application for the Blackstone River Flood Control Project during March 1971. In addition to the flood protection of major industries, this group was quite concerned about flooding on the recently completed 42" trunkline sewer along the Blackstone River to the Woonsocket city line. The probability of the destruction of this line in a repetition of the 1955 flood is quite real.

Another major concern was the possibility of the Providence and Worcester Railroad line being washed away. During the 1955 flood (flood of record) the railroad track eroded in several locations; in one Albion area (Lincoln) the bridge crossing was severely damaged and another location was between Martin Street and Mendon Road where a stretch of 1200 feet of track was displaced.

The Chamber of Commerce brief also stated: "In addition to the great economic losses at times of flooding, other serious concerns include the damage and pollution of municipal water supply wells along the river; and the damage to the Blackstone Canal (recently declared a National Historic Site) which is a valuable historic and recreational resource."

Lower Cumberland - The left bank of this reach extending from the Sayles Finishing Dam at Broad Street to the Pawtucket city line incurred a very small amount of urban damage in the 1955 flood.

Central Falls - Damage to the right bank in Central Falls was mixed urban and industrial (about $350,000 in physical losses at 1955 price levels), occurring mostly between the two railroad bridges at the downstream end of this reach where the flood limits extended as far as up High Street in some areas.

-<u>Pawtucket</u> - Greatest losses in Pawtucket were concentrated on the right bank in the commercial area around Roosevelt and Main Streets. Physical losses here amounted to $340,000 at 1955 price levels. The area has since been part of an urban renewal project and changes in damage estimates are reflected in the recorded data.

Following are some excerpts from newspapers of the day that were quoted in the report entitled "Flood Plain Information, Blackstone River, Cumberland, Lincoln, Central Falls and Pawtucket, Rhode Island, June 1971": "...Blackstone River reached its highest flood stage in history, the river rose 3-1/2 inches per hour (between 12:45 a.m. to 1:45 a.m.)..."

In Central Falls:

"...residents between the Blackstone River and High Streets were alerted to evacuate..."

In Lincoln:

"...North of John Street a Drive-In Theater being built was filled with water..."

In Pawtucket:

"...All buildings on the riverside of Roosevelt Avenue to the old police station reported flooding...

...Water ran over the retaining wall just south of the Exchange Street bridge and flooded the Municipal Building area...

...Slater Mill threatened...water filled the basement and covered the first floor..."

Losses from the most recent big flood, that of March 1968, were held down by the West Hill flood control dam. Nevertheless, damages did occur. The following newspaper excerpts describe a few sites that were affected by the near record crests of the Blackstone River.

"...The Pawtucket Water Department faced an emergency as water from the Blackstone River flooded its water purification plant in <u>Cumberland</u>...

...In <u>Pawtucket</u>, the Blackstone River was 6.5 feet above normal and there was extensive damage in city streets...

...The Sayles Finishing Plant Complex off Walker Street in Lincoln was hard hit...

...The warehouse of Roger Williams Grocery Co. off Mountain Street in Cumberland was surrounded by 6 feet of water...

...Mendon Road in Cumberland from the Lincoln town line to Broad Street was closed after it became inundated...

...Flood conditions forced closing of the westbound lanes of the George Washington Highway from the Cumberland line to the H & H Screw Co. in Lincoln

...Also closed because of flooding was the Martin Street bridge in Cumberland...

...In Central Falls, cellars were flooded in 15 homes in Notre Dame Plat adjacent to the Blackstone River...

...Several small industries and the large Lonsdale Bleachery Complex were inundated by floodwaters..."

IMPROVEMENTS DESIRED

Local Support and Desires - To afford individual citizens, municipal and State officials and other Federal agencies an opportunity to present their views and desires concerning the need and extent of improvements on flood reduction measures and other interrelated water oriented resources, four public hearings on 9, 12, 15 and 22 May 1969 were held at the initiation of the study. Though these four public hearings were intended to cover the entire Pawtucket River and Narragansett Bay Drainage Basin (PNB) study area, as mandated by seven Congressional Resolutions, two of these hearings were held in Providence, Rhode Island and Uxbridge, Massachusetts - two areas contiguous to the Blackstone River Basin.

All interested parties were invited to be present or represented at these hearings, including representatives of Federal, State, county and municipal agencies, and those commercial, industrial, civic, highway, rail, water, transportation, flood control and other interests and property owners concerned. They were afforded full opportunity to express their views concerning the character and extent of the improvements desired and the need and advisability of their execution. Sponsors of improvement measures were urged to present pertinent factual material bearing upon the general plans of improvement desired and to give detailed supporting data on the economic justification of the undertaking. Opposing interests were also urged to state the reasons for their position.

Oral statements were heard and, for accuracy of the record, all important facts and arguments were submitted in writing, some handed to the hearing officer and others mailed to his office.

Most of the attendees supported and concurred in this study. Excerpts from the record which reflect their general attitudes follow:

a. Roland Messier, Mayor of Central Falls, inquired why they have recently had yearly threats as far as floodwaters throughout Central Falls when, prior to the dams constructed in Woonsocket, they had none. He also noted that since improvements have been undertaken up north, the problem has been getting worse down south.

b. Eugene Jeffers, City Engineer from Pawtucket and representing the Mayor, suggested that a study be undertaken concerning sedimentation in the channel in the Pawtucket area. He added that dredging and/or deepening the channel in conjunction with the removal of one or two dams and the installation of another type of control, such as the bastile dam, might allow more water to pass through Pawtucket, decreasing some of the water levels to the north.

c. Selectman George St. Martin, town of Northbridge, spoke about the annual problem of flooding in his area. He pointed out the main problem might be due to silt built up along the river and of the dams that are no longer being used. He was in favor of removing some of them, and possibly relieving some of the flooding. He also expressed his discontent with the Army Engineers' lack of concern about the Blackstone River in his area.

d. Paul X. Tivnan, County Commissioner from Paxton, presented and discussed 10 recommendations formulated by the County Commissioners. These recommendations were a result of an in depth study on the severity of potential floods due to spring thaws.

e. Jules Gadoury, Selectman from the town of Blackstone, commented on how the West Hill and the Woonsocket flood control projects have left the communities in between caught in the middle, since it seems that the riverflow has increased. He was pleased to see the study undertaken and that recreational and environmental aspects were considered. He also hoped the Corps would undertake small project studies in the immediate area from St. Paul Street Bridge up to Rolling Dam.

f. John Molony, Selectman of the town of Millville, expressed his discontent at the lack of immediate action such as dredging, which would be a simple solution to 75 percent of the problem.

g. Bob Burotano, resident of the town of Northbridge, also expressed his discontent with the lack of action after all the studies that have been done.

h. Peter Larsen, resident of Blackstone, talked about flood damages due to poor land use.

i. George Peterson, Chairman of Board of Selectmen from Grafton, strongly urged completion of the study in order to bring any improvement which will reduce the threat to industry and citizens along the river.

j. Mr. Welock, from Uxbridge, emphasized conservation of the Uxbridge area as a valuable and beautiful area.

To supplement information received at these public meetings and to fully evaluate and update the inventory of the flood problems and other water resources needs, numerous informal meetings with the State agencies and individuals, citizens, companies and plants vulnerable to flooding, were initiated.

At first there was a minimum amount of interest from the local people since some of them did not or were not aware of the serious flood problems in this valley. As the study progressed and the potential flood problems surfaced, meetings became more fruitful with indications of general support and genuine willingness to participate in the investigation of the study.

Since initiation of this basin study, additional requests for Federal assistance in solving specific flood problems have been requested. Some of the requests have been considered under other existing authorities available to the Corps of Engineers, such as Section 205 of the Flood Control Act of 1948, as amended. Other requests received and processed came under the purview of the clearing and snagging authority as covered in Section 208 of the Flood Control Act of 1954, as amended.

Summaries of letters to the Corps are as follow:

26 March 1968 -- Plant Manager, Owens-Corning Corp., Ashton, Rhode Island reported a total loss of $100,000 in damages after a portion of their plant was "under water" due to flooding conditions on March 18, 1968.

28 March 1968 -- Town Administrator of Cumberland asked that Government action be taken to review their reach of the Blackstone River for possible flood protection.

11 April 1969 -- The Lonsdale Drive-In Theater sustained $40,000 damage due to flooding in March 1968 and $10,000 damage from the flood of March 1969. They inquired what could be done to eliminate these flooding conditions.

19 March 1971 -- A brief supporting an application for a Blackstone River Flood Control Project was prepared by Robert F. Burns, Mayor, city of Pawtucket; Roland E. Messier, Mayor, city of Central Falls, Edward J. Hayden, Administrator, town of Cumberland; Barry J. Farrands, Administrator, town of Lincoln; and the Pawtucket-Blackstone Valley Chamber of Commerce and was distributed to the Honorable Frank Light, Governor, State of Rhode

Island; the Honorable John O. Pastore, United States Senator, the Honorable Claiborne Pell, United States Senator; the Honorable Fernand J. St. Germain, United States Representative, 1st Congressional District; and the Honorable Albert O. Tienan, United States Representative, 2nd Congressional District. A copy of this brief was submitted to the Division Engineer (NED) by Congressman St. Germain.

Some of the highlights from this brief follow:

1. The signatories, on behalf of their respective communities, and on behalf of business firms involved, respectfully petitioned the State of Rhode Island and Government of the United States to establish a specific project for remedies from flooding on the lower Blackstone River.

2. Their concern about the damages from flooding have been intensified by the completion of a 42" trunkline sewer along the Blackstone River to the Woonsocket city line. The possibility of the destruction of this sewerline in a repetition of the 1938 or 1955 floods is quite real. One section of the Providence and Worcester Railroad, beside which the sewerline is laid was completely washed away in 1955.

3. In addition to the great economic losses due to flooding, other serious concerns include the damage and pollution of municipal water supply wells along the river; the damage to the Blackstone Canal (recently declared a National Historic Site) which is a valuable historic and recreational resource. Realizing the potential flood danger, especially in the low-lying areas and also the encroachment that has occurred and continues to occur, all the study area communities along the Blackstone River have applied for flood insurance assistance under the National Flood Insurance Program except the town of Paxton, Massachusetts.

Other requests for improvements include channel modification involving one or a combination of the following methods:

a. Widening, deepening and channel realignment of certain stretches of river.

b. Improvement of waterway areas at bridges, culverts and at other constriction points.

Selective planting and/or revetment works for alleviating erosion problems.

d. Removal of vegetation, overhanging trees, shrubs and

accumulated silt and debris at critical points.

Numerous other requests were made involving the removal or structural stabilization of old dams as well as the modification of existing lakes, ponds and reservoirs to add a measure of flood protection.

New Threat Added - In 1970, construction of a 42" trunk sewerline from Lonsdale to Woonsocket was completed. Most of this pipeline was laid along the riverbank and is almost entirely in the flood zone. Damage to the sewerline could occur if there is a flood greater than the 1968 flood.

In the event that a break occurred in the sewerline caused by a flood, virtually every industry that lies in the Blackstone River Valley could be forced to shut down. This would greatly damage the economy in this area.

WITHOUT CONDITION PROFILE - (The future if no Federal action is taken) - The without condition alternative shifts the major responsibility and burden of flood protection to those who live and work on the flood plain. Under the without condition alternative, no new regional or local structural projects are built as possible solutions to reduce flood damages.

Without condition means forfeiting potential benefits such as construction related jobs, reduced fear of deaths or accidents from flooding, reduced flood damages, increased water supply and additional possible water related recreational facilities. It also means avoiding the adverse impacts resulting from structural solutions.

For the eight communities designated as susceptible to flood damage in the future, the combined 1970 population was 167,000. The projected 1990 population is 179,000, or an increase of 12,000. This means that additional areas presently vegetated will be turned into roads and residential developments. Some of this growth will likely occur in the flood plain.

The Flood Disaster Prevention Act of 1973, PL 93-234 established regulations for participating communities under the National Flood Insurance Program. The communities Lincoln, Central Falls, East Providence, Providence, Pawtucket and Woonsocket, Rhode Island and Blackstone, Massachusetts are currently under the regular program. This indicates that these seven communities have established flood plain management regulations aimed at reducing future flood losses within the 100-year flood plain. The communities of Cumberland and North

Smithfield, Rhode Island and Northbridge, Uxbridge, Millville, Grafton, Millbury, Sutton and Worcester, Massachusetts are under the "emergency program" meaning they have shown an intent toward establishing and enforcing the 100-year flood limits.

Existing structures within the 100-year flood plain are eligible for low cost flood insurance at a highly subsidized rate within certain limits. New development within this area is allowed, but it must be either elevated above the 100-year flood stage, or in the case of commercial and industrial development, floodproofed to this elevation. The effect of this is that future damages due to occurrence of a 100-year flood to new development will be reduced. However, damages due to flooding from events above the 100-year and up to the design flood (greater than a 500-year storm) are expected to occur.

Urbanization outside the flood plain will cause increased runoff resulting in flood levels higher in the future for a recurring storm than in the past. This means that today's storm will cause even greater damage in the future.

<u>The Future Population</u> - The Southeastern New England (SENE) Study of Water and Related Land Resources has provided the most comprehensive projections of population and economic activity to date for the entire area encompassed by the Blackstone Valley. The projections they provide for the future population of cities and towns in the region are based on two important considerations:

1. They are an allocation of the 1972 OBERS projections of regional economic activity in the U.S. done for the U.S. Water Resources Council.

2. The allocations are based on SENE projections of regional economic activity which appears, on the surface, to be an extrapolation of the recent southeastern New England trend toward a service oriented export base (particularly for Boston) and the continued shift away from the textile manufacturing base toward the various metal working and electrical-mechanical machine industries.

The SENE projections indicate a decrease in the rate of decline of urban areas, substantial increases in the population and density of the inner ring of towns around these urban areas (e.g. Shrewsbury, Millbury, Auburn, and Grafton around Worcester, and all of the Rhode Island suburban and rural towns between Woonsocket and Providence), and a low to moderate growth rate for the towns along the middle reaches of the river in Massachusetts. The implication, in terms of urbanization and density, is that the

inner ring of towns around the urban centers would absorb a disproportionately large share of new growth, while the outer ring of towns substantially retains its rural nature with densities under 500 persons per square mile.

Simple aging of the populations of the region surrounding the Blackstone Valley can be expected to produce dramatic changes in the age composition and location of the population with resulting changes in labor force, in nouseholds, in land use, and in demand for water resources. The fact that the aging of the Blackstone Valley population will be similar to that of the United States is reflected by the similarity in their age compositions.

Figure 1-3, United States Population by Age, 1970-1990, from the U.S. Bureau of the Census, shows the broad outline of the anticipated change as it will occur in the United States and also the Blackstone Valley. The elements of the change will include:

a. Decrease in the number of teenagers in the population.

b. Substantial increase in both the percentage and absolute number of young adults, say from 25 to 34 years old.

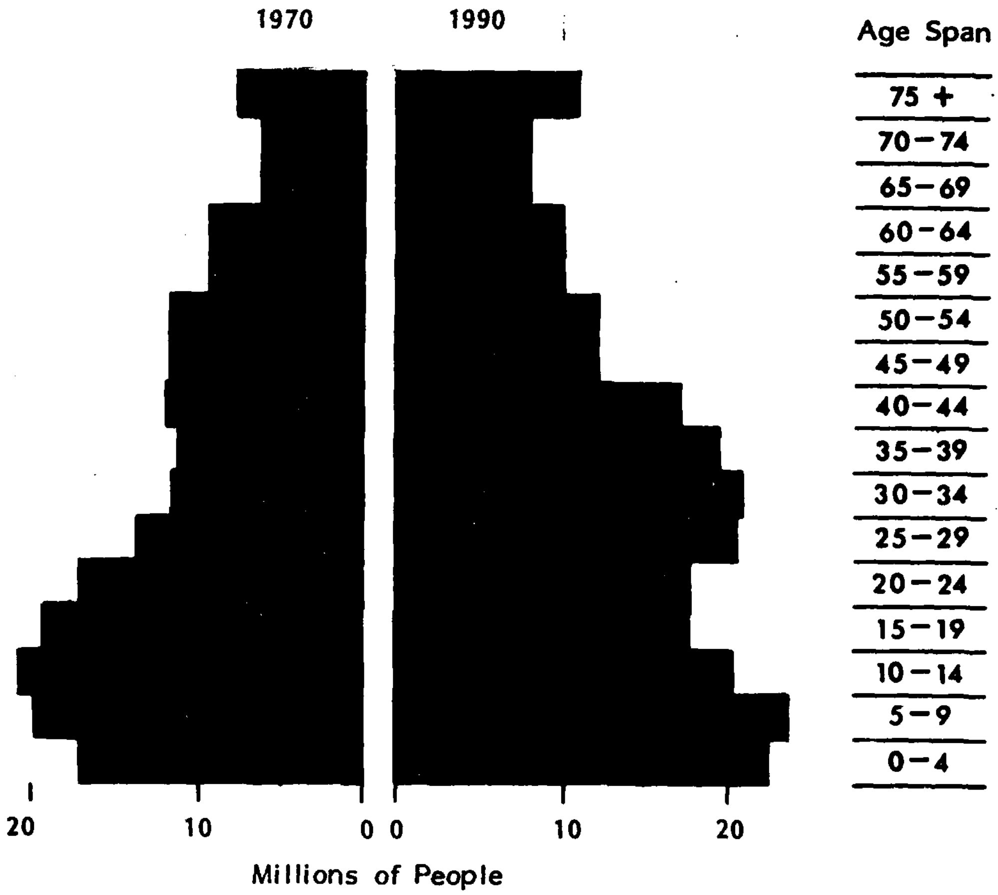
c. Decrease in the percentage of people 45 to 54 years old.

d. Significant increase in the percentage and absolute number of senior citizens, people over 65 years old; and perhaps most interestingly,

e. Significant increases in the number of younger children resulting from the ultimate reproduction of the post World War II baby boom.

Table1-13 displays population projections for the impact area communities as determined by the Central Massachusetts Regional Planning Commission and the Rhode Island Statewide Planning Program for their respective communities. The older central cities of Central Falls and Pawtucket show continual declines in population with all other communities showing increases. The greatest increases are expected in Lincoln with 23.4 between 1975 and 2020, and Sutton with 32.8 percent between 1975 and 2000. The Rhode Island communities still remain more densely settled.

Future Floods - In developing the flood picture of a river basin, consideration should be given to those flood which have occurred and to those floods which could occur in the future. The following paragraphs describe an intermediate regional flood and a



UNITED STATES POPULATION BY AGE
1970 AND 1990

Source: Statistical Abstract of the United States, 1973.

FIGURE 1-3

TABLE 13

POPULATION PROJECTIONS 1990, 2000, 2020

	1975	1990	2000	2020	% Change	Pop. Density 2000
Millbury	12,121	13,500	14,000	N.A.	15.5	875
Sutton	4,969	6,150	6,600	N.A.	32.8	201
Grafton	10,630	11,300	11,700	N.A.	10.1	513
Northbridge	12,165	12,800	13,400	N.A.	10.2	779
Uxbridge	8,528	9,000	9,200	N.A.	7.9	311
Millville	1,744	1,850	1,950	N.A.	11.8	397
Blackstone	6,486	6,900	7,100	N.A.	9.5	633
Cumberland	27,648	29,400	30,800	32,500	17.5	1,136
Lincoln	17,177	19,600	20,400	21,200	23.4	1,096
Central Falls	16,689	11,300	11,000	10,900	-34.7	9.166
Pawtucket	72,024	62,300	60,500	60,000	-16.7	6,875

Source for MA communities: Central Massachusetts Regional Planning Commission

Source for RI communities: Rhode Island Statwide Planning Program, Revised 1979

standard project flood in the vicinity of Cumberland, Lincoln, Central Falls and Pawtucket, Rhode Island. A flood comparable to the standard project flood can reasonably be expected. The intermediate regional flood may be expected to occur more frequently but will not be as severe as the standard project flood.

Large floods have been experienced in the past on streams in the general geographical and physiographical region of the study area. Heavy storms similar to those causing these floods could occur over the watershed of the Blackstone River. In this event, floods would result on this stream comparable in size with those experienced on neighboring streams. It is therefore desirable, in connection with any determination of future floods which may occur on the Blackstone River, to consider storms and floods that have occurred in the region on watersheds whose topography, watershed cover and physical characteristics are similar to those of this stream.

Future Economy - SENE projections of economic activity in southeastern New England predict an overall continuation of the basic decline in the proportionate importance of manufacturing, with the exception of machinery, fabricated metals and ordinance, and transportation equipment; growth in the financial and government sector; and substantial growth in services. In the Worcester-Fitchburg-Leominster SENE subarea, manufacturing is expected to decline from a 45.3 percent share of that region's total earnings in 1969 to 37.3 percent in 1990 and 31.4 percent in 2020. At the same time, the service industries are expected to grow in their share of total earnings from 13.9 percent in 1969 to 17.4 percent in 1990 and 20.3 percent in 2020, mostly in the city of Worcester itself, which is becoming a service center for the expanding western fringe of the Boston metropolitan area in spite of the influence of Boston as regional center for government finance, communication and service activities. The Fitchburg-Leominster portion of this subarea is significantly more manufacturing based than the city of Worcester itself, and is expected to remain so.

Similarly, in the Providence-Pawtucket-Warwick subarea, SENE predicts manufacturing's share of earnings will decline from 36.9 percent in 1969 to 31.1 percent in 1990 and 27.2 percent in 2020, while services grow from 15.0 percent to 17.2 and 19.0 percent for the same periods. Growth is also projected for wholesale and retail trade and government, relative to other industries.

When just the industries making up the basic or export segment of the area economy (i.e. those who sell goods or services

to consumers outside the region) are examined, the shift to a service based economy is less evident, especially in the Worcester area. Table 1-22, SENE Forecasts of Industry Share of Regional Export Earnings 1959-1990, indicates each industry's share of total export earnings. Manufacturing industries accounted for nearly 100 percent of the Worcester-Fitchburg-Leominster (WFL) subarea's export base in 1959 and 96 percent of the Providence-Pawtucket-Warwick (PPW) subarea base for the same year. By 1990, SENE expects that manufacturing will still comprise about 96 percent of the WFL export earnings and about 80 percent of the PPW export earnings.

Of the manufacturing industries in Table 1-14 (Regional Export Earnings), miscellaneous manufacturing (primarily jewelry) shows promise for substantial growth while the metal working and machinery industries, although losing in their share of total export earnings, still make up a large share of manufacturing earnings. The textile mill products exhibit substantial decline in regional importance.

The economic character of the region surrounding the Blackstone Valley appears likely to be altered in the future as a result of recent or impending large scale economic changes resulting from the energy crisis, dollar devaluation, restructuring of the northeastern Unites States railroad system, the closing or reduced activity of most military bases in the region, the possible development of oil and/or gas resources on Georges Bank, and the trends toward ever larger bulk carriers for ocean shipping. The net result of all these changes, together with the need for substantially more jobs, is difficult to appraise, especially toward energy importance and consequently toward foreign trade in general.

Overall, the total picture appears to lead toward more diversity in the region's manufacturing. If foreign policy tends toward trade expansion, the unique deep-draft capability of Narragansett Bay would add to the importance of the Blackstone Valley, as one of the best rail routes to Narragansett Bay from the interior of the Nation. All these changes indicate substantial demand for industrial, warehousing and transportation land in the region surrounding the Blackstone.

The effects of the predicted industrial growth mix on the economic well being of the watershed's inhabitants can be measured in the personal income those industries are expected to return. Figure 1-4, Total Personal Income, 1950 to 2020, shows that according to the SENE study, the economy of the two subareas comprising the Blackstone Valley is expected to expand at a rate

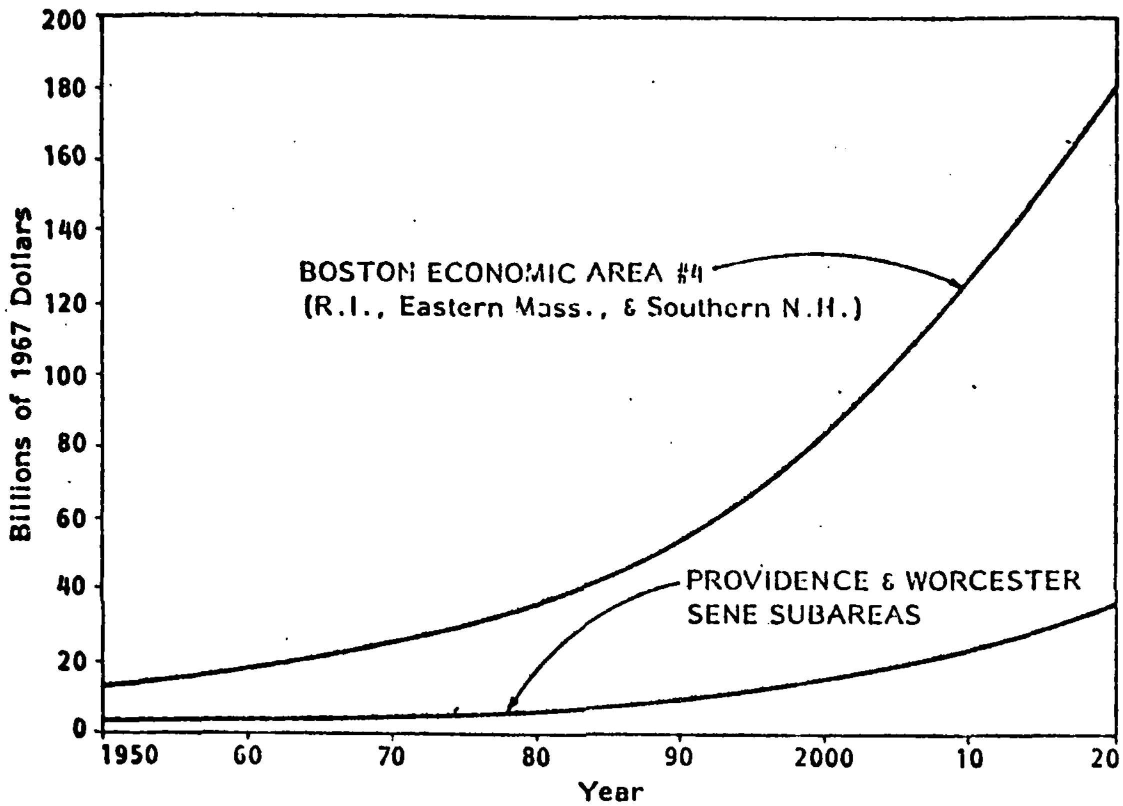
TABLE 1-14

SENE FORECASTS OF INDUSTRY SHARE OF REGIONAL EXPORT EARNINGS 1959 - 1990

Selected Industry	1959 % of Export Base Earnings	1959 Rank	1969 % of Export Base Earnings	1969 Rank	1990 % of Export Base Earnings	1990 Rank
Worcester-Fitchburg-Leominster Area						
Miscellaneous Manufacturing	32.4	1	29.4	1	32.3	1
Machinery, excl. Electric	28.8	2	28.1	2	25.0	2
Textile Mill Products	10.6	3	5.5	5	1.8	10
Primary Metals	10.0	4	7.7	4	5.0	5
Paper & Allied Products	D	5	D	6	D	8
Fabricated Metals & Ordnance	5.0	6	11.5	3	13.3	3
Lumber & Furniture	4.9	7	4.0	7	2.3	9
Apparel & Other Textiles	1.1	8	-	-	-	-
Printing & Publishing	.4	9	2.0	10	3.8	7
Professional Services	-	-	4.0	8	8.8	4
Utilities (Elect, Gas, San.)	-	-	3.1	9	4.1	6
Providence-Pawtucket-Warwick Area						
Miscellaneous Manufacturing	43.3	1	54.5	1	61.2	1
Textile Mill Products	36.8	2	22.3	2	12.6	2
Primary Metals	6.4	3	4.2	5	2.6	6
Machinery, excl. Electric	5.3	4	.3	10	-	-
Fabricated Metals & Ordnance	4.6	5	4.5	4	.6	11
Utilities (Elec, Gas, San.)	1.4	6	1.1	9	1.2	10
Finance, Insurance & Real Estate	1.3	7	2.1	7	2.5	9
Trucking & Warehousing	.4	8	.1	12	.6	12
Communications	.4	9	.3	11	-	-
Forestry & Fisheries	-	10	-	-	-	-
Professional Services	-	-	6.4	3	2.6	7
Wholesale & Retail Trade	-	-	2.6	6	6.7	3
Printing & Publishing	-	-	1.6	8	2.5	8
Contract Construction	-	-	-	-	3.5	4
State & Local Government	-	-	-	-	3.4	5

D=Deleted to avoid disclosure of confidential data

Source: "Southeastern New England Study of Water & Related Land Resources", NERBC, 1973, Appendix Table 12



TOTAL PERSONAL INCOME
1950 TO 2020

SOURCE: "Southeastern New England Study of Water and Related Land Resources", Interim Report - New England River Basins Commission, March, 1973

FIG. 1-4

significantly slower than the southeastern New England region as a whole.

The per capita personal income of the watershed's inhabitants will apparently converge toward the per capita income level for the Nation:

	Per Capita Personal Income							
	1950		1969		1990		2020	
	Amt	Index	Amt	Index	Amt	Index	Amt	Index
United States	2,065	1.00	3,416	1.00	6,165	1.00	14,260	1.00
BEA* Econ. Area #4	2,231	1.08	3,696	1.08	6,482	1.05	14,520	1.02
Worc. SENE Subarea	2,245	1.09	3,352	0.98	6,122	0.99	14,128	0.99
Prov. SENE Subarea	2,291	1.11	3,515	1.03	6,281	1.02	14,518	1.02

*BEA - Burea of Economic Analysis

The southeastern New England region (BEA Economic Area #4) is expected to decline in its per capita income relative to the U.S. from 8 percent higher than the U.S. figure in 1950 and 1969 to only 2 percent higher in 2020. The Providence subarea also has enjoyed a per capita income higher than the Nation's (11 percent higher in 1950) but is also converging toward the U.S. total. Per capita income in the Worcester subarea is expected to continue at one to two percent lower than that of the Nation.

Future Development- The imminent demographic and economic changes described above can be expected to create substantial demand for the development of land in the Blackstone region. It will be shown that the best soil conditions for urban and industrial development and for on site water and sewage disposal lie close to the river. In addition a major rail line lies along its banks, and good highway access is not far away. As a result, new growth within the basin can be expected to be disproportionately concentrated along the river making both its control and the development of its water resources far more important for the future than for the present.

In a recent study financed and administered by the Rhode Island and Massachusetts Departments of Environmental Management and by the Rhode Island and Massachusetts Historic Commissions the feasibility of developing a linear park system along the Blackstone River was investigated. It is hoped that the development of a river/canal park system for recreational purposes would serve the needs of an urban population, preserve the early industrial history of the valley, retain the natural beauty, and enhance the character and economic well-being of the communities along the river.

__Summary of the Socio-Economic Outlook__ - The prospects for economic growth within the Blackstone Valley appear to be very different for the areas already substantially urbanized, the suburban fringe areas, and the nonurbanized areas of the watershed. The basic nature of the growth in these areas is a function of the future industrial mix of the region, which appears to be difficult to appraise in anything other than a speculative manner in light of the state of general flux in national economic and environmental policies and attitudes.

Growth in the small metal components industries traditional to the region is expected to occur within and at the fringes of the urbanized area because of their relatively small demands on land and water resources and greater demand for skilled labor.

On the other hand, the prospect for materials processing industries gaining a substantial share of the region's resources and generating an even greater share of the region's earnings is very real. The greatest prospects are for the development of petrochemical industries as the oil refining capacity of the region increases substantially and for warehouse-transfer industries as the unique deep-draft bulk shipping capabilities of Narragansett Bay are developed. The site requirements for these industries are markedly different from traditional regional industries as they are likely to need individual sites of much greater relative size, large scale rail transfer points and large volumes of process water. In short, these industries seem ideally suited for the wide sand and gravel terraces along the middle reaches of the river which are predominantly rural in their character today.

The outlook then, is that certain portions of the Blackstone Valley, especially lands close to the river, can be expected to become substantially urbanized over the next decade, 1975 to 1985, barring a major war or depression. Land uses expected along the river will probably include substantial industrial, warehousing and transportation activities of regional and, possibly, national economic importance.

The impact of this on the allocation of population throughout the region could be substantial. There is little doubt that the suburban fringes will continue to grow at substantial rates, but given the growing cost of travel and the resulting desire of people to be close to their jobs, industrial development of the rural middle reaches of the river could very well lead to rapid "suburbanization" of those lands. Again, this development is likely to stay close to the river for good well water supply and sewage leaching because of the difficulty in developing the glacial tills of the surrounding hillsides.

City of Central Falls

Removal of over 200 feet of sand and gravel bars and protruding boulders;

Widening 400 linear feet of channel by an additional 20 feet;

Removal of rubbish and debris and clearing of trees and brush from riverbanks;

Removal of snags from the channel.

Spoil areas were established for the removed materials, and a considerable quantity of the excavated material was utilized in the construction of temporary protective dikes. As a result of field surveys, other problems were noted and recommendations were made to the communities for permanent flood protection works.

Navigation - The existing Seekonk River Navigation Project was adopted in 1905 and modified in 1909, 1919 and 1922. It consists of a channel 16 feet deep from Red Bridge, which is located about 1.3 miles upstream of Wilkes Barre Pier in East Providence, to the Division Street Bridge in Pawtucket -- at a total distance of about 3.4 miles. The project was completed in 1927 at a cost of $406,000, $68,000 of which was contributed by local interests as required under the conditions of local cooperation for bulkheaded spoil disposal areas.

Other Non-Federal Projects

Commonwealth of Massachusets - Subsequent to and a result of severe damages the August 1955 flood, the Massachusetts Department of Public Works, Division of Waterways, completed modification and restoration of numerous damaged projects within Massachusetts portion of the Blackstone River Watershed. A synopsis of completed work is as follows:

Worcester

Flood control work for Beaver Brook and Middle River to relieve flooding in Webster Square. Project completed in August 1960.

Stream channel improvements and reinforced concrete box culvert along Mill Brook. Completed November 1961.

Stream channel improvement along West Tatnuck Brook. Completed May 1962.

Channel improvement at Marshall Pond and Mill Brook. Completed November 1964.

Construction of reinforced concrete box culvert and incidental work along Mill Brook. Completed July 1970. Total cost $652,047.

Millbury

Channel improvements along Kitchen Brook and the Blackstone River in the upstream portion of the town of Millbury. Completed prior to 1960.

Grafton

Channel improvement and diversion of the Blackstone River near Pleasant Street in the village of Saunderstown (Grafton) into two channels -- the existing channel plus a new channel following the old Blackstone Canal alignment was completed.

Repairs and renovations to Irish and Hovey Dams. Completed April 1977. Total cost $20,050.

Blackstone

Replace bridge and construct flood contol wall and other river improvements. Completed October 1961. Total cost $227,490.

Milford

Channel improvement along Charles River. Completed June 1967. Total cost $293,248.

Auburn

Stream improvement along Boyce Street Brook. Completed July 1968. Total cost $108,101.

Shrewsbury

Stream improvements, reinforced concrete box culverts, reinforced retaining walls, concrete flumes, reinforced concrete dam, headwalls, channel excavation and incidental work in Kings Brook. Completed May 1970. Total cost $213,791.

North Attleboro

Spillway, access ramp and facilities at Falls Pond.

Completed October 1972. Total cost $218,999.

Northbridge

Reconstruction of Kupfer Dam. Completed August 1958.

Stone slope protection work at Riverdale Street. Completed April 1962.

Uxbridge

Reconstruction of Rice City Dam.

Supplementing these projects, the Division of Waterways has also reconstructed, since the August 1955 flood, numerous bridges across the Blackstone River that were either destroyed or severely damaged. New Channel improvements required by recent interstate highway construction near and in the vicinity of Worcester have also been completed.

State of Rhode Island - Other than bridges reconstructed by non-Federal interests in conjunction with two Woonsocket local protective works, no flood control projects have been undertaken or completed by the State of Rhode Island.

Public - On September 9, 1972, the Blackstone River Watershed Association established "Project Zap" and launched the first of several phases in a massive cleanup campaign for the Blackstone River. On this day, "Project Zap" mobilized 10,000 volunteers to remove more than 10,000 tons of more obvious debris from a 14-mile reach of the Blackstone River that stretches from Pawtucket, Rhode Island to the Woonsocket Falls Dam upstream of South Main Street Bridge in Woonsocket, Rhode Island.

"Zap II," the second of several phases to cleanup the Blackstone River, was held in the fall of 1977. About 1700 tons of debris was removed from the Blackstone River adjacent to the communities of Blackstone, Millville, Uxbridge and Northbridge, all of which are located in Massachusetts.

"Project Zap" was the first step in a continuing community effort to enhance the beauty of the riverbanks and river environment. Concurrent with this cleanup operation, a further thrust will be made to create and establish a series of ministrip or linear parks along the flood plain area of the river. This would inaugurate a series of recreational sites and areas as part of the Interstate Park system and, possibly, of the National Recreational and Historic Parks managed by the U.S. Department of

the Interior. Such a bill was introduced in the U.S. Congress by Representative Fernand St. Germain, 1st Congressional District of the State of Rhode Island.

IMPROVEMENTS DESIRED

Local Support and Desires - To afford individual citizens, municipal and State officials and other Federal agencies an opportunity to present their views and desires concerning the need and extent of improvements on flood reduction measures and other interrelated water oriented resources, four public hearings on 9, 12, 15 and 22 May 1969 were held at the initiation of the study. Though these four public hearings were intended to cover the entire Pawtucket River and Narragansett Bay Drainage Basin (PNB) study area, as mandated by seven Congressional Resolutions, two of these hearings were held in Providence, Rhode Island and Uxbridge, Massachusetts - two areas contiguous to the Blackstone River Basin.

All interested parties were invited to be present or represented at these hearings, including representatives of Federal, State, county and municipal agencies, and those commercial, industrial, civic, highway, rail, water, transportation, flood control and other interests and property owners concerned. They were afforded full opportunity to express their views concerning the character and extent of the improvements desired and the need and advisability of their execution. Sponsors of improvement measures were urged to present pertinent factual material bearing upon the general plans of improvement desired and to give detailed supporting data on the economic justification of the undertaking. Opposing interests were also urged to state the reasons for their position.

Oral statements were heard and, for accuracy of the record, all important facts and arguments were submitted in writing, some handed to the hearing officer and others mailed to his office.

Most of the attendees supported and concurred in this study. Excerpts from the record which reflect their general attitudes follow:

a. Roland Messier, Mayor of Central Falls, inquired why they have recently had yearly threats as far as floodwaters throughout Central Falls when, prior to the dams constructed in Woonsocket, they had none. He also noted that since improvements have been undertaken up north, the problem has been getting worse down south.

b. Eugene Jeffers, City Engineer from Pawtucket and representing the Mayor, suggested that a study be undertaken concerning sedimentation in the channel in the Pawtucket area. He added that dredging and/or deepening the channel in conjunction with the removal of one or two dams and the installation of another type of control, such as the bastile dam, might allow more water to pass through Pawtucket, decreasing some of the water levels to the north.

c. Selectman George St. Martin, town of Northbridge, spoke about the annual problem of flooding in his area. He pointed out the main problem might be due to silt built up along the river and of the dams that are no longer being used. He was in favor of removing some of them, and possibly relieving some of the flooding. He also expressed his discontent with the Army Engineers' lack of concern about the Blackstone River in his area.

d. Paul X. Tivnan, County Commissioner from Paxton, presented and discussed 10 recommendations formulated by the County Commissioners. These recommendations were a result of an in depth study on the severity of potential floods due to spring thaws.

e. Jules Gadoury, Selectman from the town of Blackstone, commented on how the West Hill and the Woonsocket flood control projects have left the communities in between caught in the middle, since it seems that the riverflow has increased. He was pleased to see the study undertaken and that recreational and environmental aspects were considered. He also hoped the Corps would undertake small project studies in the immediate area from St. Paul Street Bridge up to Rolling Dam.

f. John Molony, Selectman of the town of Millville, expressed his discontent at the lack of immediate action such as dredging, which would be a simple solution to 75 percent of the problem.

g. Bob Burotano, resident of the town of Northbridge, also expressed his discontent with the lack of action after all the studies that have been done.

h. Peter Larsen, resident of Blackstone, talked about flood damages due to poor land use.

i. George Peterson, Chairman of Board of Selectmen from Grafton, strongly urged completion of the study in order to bring any improvement which will reduce the threat to industry and citizens along the river.

j. Mr. Welock, from Uxbridge, emphasized conservation of the Uxbridge area as a valuable and beautiful area.

To supplement information received at these public meetings and to fully evaluate and update the inventory of the flood problems and other water resources needs, numerous informal meetings with the State agencies and individuals, citizens, companies and plants vulnerable to flooding, were initiated.

At first there was a minimum amount of interest from the local people since some of them did not or were not aware of the serious flood problems in this valley. As the study progressed and the potential flood problems surfaced, meetings became more fruitful with indications of general support and genuine willingness to participate in the investigation of the study.

Since initiation of this basin study, additional requests for Federal assistance in solving specific flood problems have been requested. Some of the requests have been considered under other existing authorities available to the Corps of Engineers, such as Section 205 of the Flood Control Act of 1948, as amended. Other requests received and processed came under the purview of the clearing and snagging authority as covered in Section 208 of the Flood Control Act of 1954, as amended.

Summaries of letters to the Corps are as follow:

26 March 1968 -- Plant Manager, Owens-Corning Corp., Ashton, Rhode Island reported a total loss of $100,000 in damages after a portion of their plant was "under water" due to flooding conditions on March 18, 1968.

28 March 1968 -- Town Administrator of Cumberland asked that Government action be taken to review their reach of the Blackstone River for possible flood protection.

11 April 1969 -- The Lonsdale Drive-In Theater sustained $40,000 damage due to flooding in March 1968 and $10,000 damage from the flood of March 1969. They inquired what could be done to eliminate these flooding conditions.

19 March 1971 -- A brief supporting an application for a Blackstone River Flood Control Project was prepared by Robert F. Burns, Mayor, city of Pawtucket; Roland E. Messier, Mayor, city of Central Falls, Edward J. Hayden, Administrator, town of Cumberland; Barry J. Farrands, Administrator, town of Lincoln; and the Pawtucket-Blackstone Valley Chamber of Commerce and was distributed to the Honorable Frank Light, Governor, State of Rhode

Island; the Honorable John O. Pastore, United States Senator, the Honorable Claiborne Pell, United States Senator; the Honorable Fernand J. St. Germain, United States Representative, 1st Congressional District; and the Honorable Albert O. Tienan, United States Representative, 2nd Congressional District. A copy of this brief was submitted to the Division Engineer (NED) by Congressman St. Germain.

Some of the highlights from this brief follow:

1. The signatories, on behalf of their respective communities, and on behalf of business firms involved, respectfully petitioned the State of Rhode Island and Government of the United States to establish a specific project for remedies from flooding on the lower Blackstone River.

2. Their concern about the damages from flooding have been intensified by the completion of a 42" trunkline sewer along the Blackstone River to the Woonsocket city line. The possibility of the destruction of this sewerline in a repetition of the 1938 or 1955 floods is quite real. One section of the Providence and Worcester Railroad, beside which the sewerline is laid was completely washed away in 1955.

3. In addition to the great economic losses due to flooding, other serious concerns include the damage and pollution of municipal water supply wells along the river; the damage to the Blackstone Canal (recently declared a National Historic Site) which is a valuable historic and recreational resource. Realizing the potential flood danger, especially in the low-lying areas and also the encroachment that has occurred and continues to occur, all the study area communities along the Blackstone River have applied for flood insurance assistance under the National Flood Insurance Program except the town of Paxton, Massachusetts.

Other requests for improvements include channel modification involving one or a combination of the following methods:

a. Widening, deepening and channel realignment of certain stretches of river.

b. Improvement of waterway areas at bridges, culverts and at other constriction points.

Selective planting and/or revetment works for alleviating erosion problems.

d. Removal of vegetation, overhanging trees, shrubs and

accumulated silt and debris at critical points.

Numerous other requests were made involving the removal or structural stabilization of old dams as well as the modification of existing lakes, ponds and reservoirs to add a measure of flood protection.

New Threat Added - In 1970, construction of a 42" trunk sewerline from Lonsdale to Woonsocket was completed. Most of this pipeline was laid along the riverbank and is almost entirely in the flood zone. Damage to the sewerline could occur if there is a flood greater than the 1968 flood.

In the event that a break occurred in the sewerline caused by a flood, virtually every industry that lies in the Blackstone River Valley could be forced to shut down. This would greatly damage the economy in this area.

WITHOUT CONDITION PROFILE - (The future if no Federal action is taken) - The without condition alternative shifts the major responsibility and burden of flood protection to those who live and work on the flood plain. Under the without condition alternative, no new regional or local structural projects are built as possible solutions to reduce flood damages.

Without condition means forfeiting potential benefits such as construction related jobs, reduced fear of deaths or accidents from flooding, reduced flood damages, increased water supply and additional possible water related recreational facilities. It also means avoiding the adverse impacts resulting from structural solutions.

For the eight communities designated as susceptible to flood damage in the future, the combined 1970 population was 167,000. The projected 1990 population is 179,000, or an increase of 12,000. This means that additional areas presently vegetated will be turned into roads and residential developments. Some of this growth will likely occur in the flood plain.

The Flood Disaster Prevention Act of 1973, PL 93-234 established regulations for participating communities under the National Flood Insurance Program. The communities Lincoln, Central Falls, East Providence, Providence, Pawtucket and Woonsocket, Rhode Island and Blackstone, Massachusetts are currently under the regular program. This indicates that these seven communities have established flood plain management regulations aimed at reducing future flood losses within the 100-year flood plain. The communities of Cumberland and North

Smithfield, Rhode Island and Northbridge, Uxbridge, Millville, Grafton, Millbury, Sutton and Worcester, Massachusetts are under the "emergency program" meaning they have shown an intent toward establishing and enforcing the 100-year flood limits.

Existing structures within the 100-year flood plain are eligible for low cost flood insurance at a highly subsidized rate within certain limits. New development within this area is allowed, but it must be either elevated above the 100-year flood stage, or in the case of commercial and industrial development, floodproofed to this elevation. The effect of this is that future damages due to occurrence of a 100-year flood to new development will be reduced. However, damages due to flooding from events above the 100-year and up to the design flood (greater than a 500-year storm) are expected to occur.

Urbanization outside the flood plain will cause increased runoff resulting in flood levels higher in the future for a recurring storm than in the past. This means that today's storm will cause even greater damage in the future.

The Future Population - The Southeastern New England (SENE) Study of Water and Related Land Resources has provided the most comprehensive projections of population and economic activity to date for the entire area encompassed by the Blackstone Valley. The projections they provide for the future population of cities and towns in the region are based on two important considerations:

1. They are an allocation of the 1972 OBERS projections of regional economic activity in the U.S. done for the U.S. Water Resources Council.

2. The allocations are based on SENE projections of regional economic activity which appears, on the surface, to be an extrapolation of the recent southeastern New England trend toward a service oriented export base (particularly for Boston) and the continued shift away from the textile manufacturing base toward the various metal working and electrical-mechanical machine industries.

The SENE projections indicate a decrease in the rate of decline of urban areas, substantial increases in the population and density of the inner ring of towns around these urban areas (e.g. Shrewsbury, Millbury, Auburn, and Grafton around Worcester, and all of the Rhode Island suburban and rural towns between Woonsocket and Providence), and a low to moderate growth rate for the towns along the middle reaches of the river in Massachusetts. The implication, in terms of urbanization and density, is that the

inner ring of towns around the urban centers would absorb a disproportionately large share of new growth, while the outer ring of towns substantially retains its rural nature with densities under 500 persons per square mile.

Simple aging of the populations of the region surrounding the Blackstone Valley can be expected to produce dramatic changes in the age composition and location of the population with resulting changes in labor force, in households, in land use, and in demand for water resources. The fact that the aging of the Blackstone Valley population will be similar to that of the United States is reflected by the similarity in their age compositions.

Figure 1-21, United States Population by Age, 1970-1990, from the U.S. Bureau of the Census, shows the broad outline of the anticipated change as it will occur in the United States and also the Blackstone Valley. The elements of the change will include:

a. Decrease in the number of teenagers in the population.

b. Substantial increase in both the percentage and absolute number of young adults, say from 25 to 34 years old.

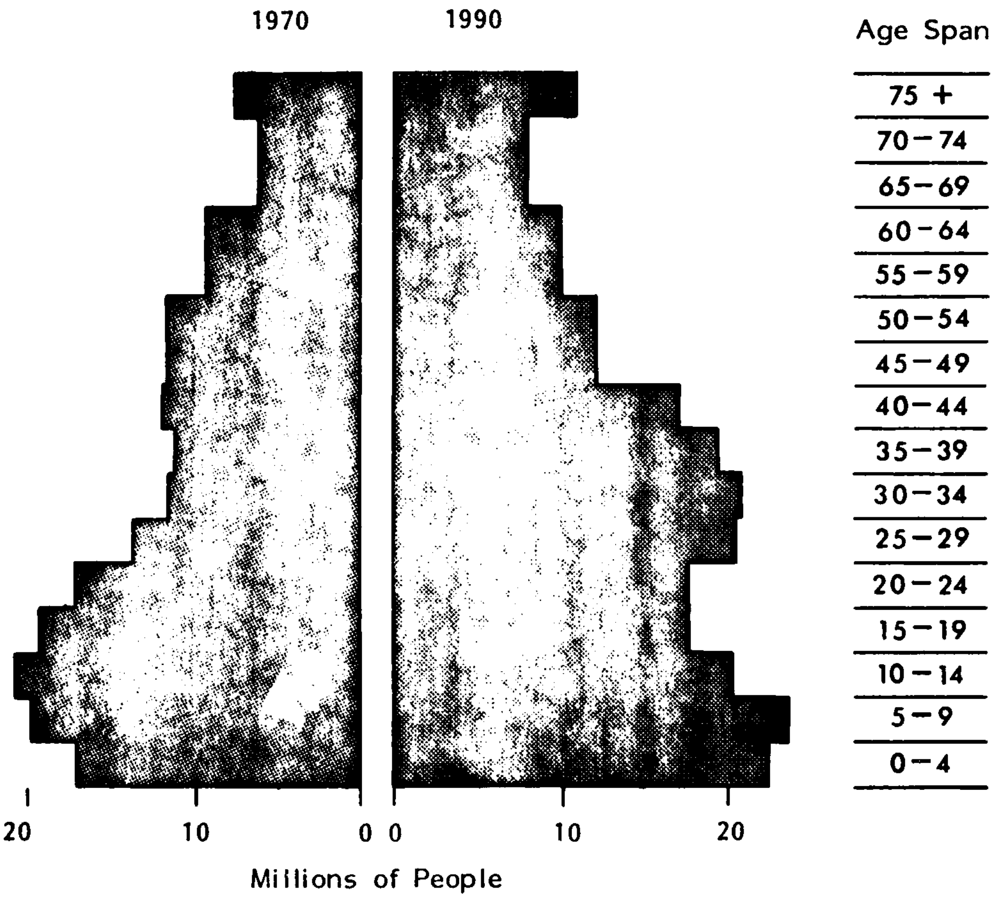
c. Decrease in the percentage of people 45 to 54 years old.

d. Significant increase in the percentage and absolute number of senior citizens, people over 65 years old; and perhaps most interestingly,

e. Significant increases in the number of younger children resulting from the ultimate reproduction of the post World War II baby boom.

Table 1-21 displays population projections for the impact area communities as determined by the Central Massachusetts Regional Planning Commission and the Rhode Island Statewide Planning Program for their respective communities. The older central cities of Central Falls and Pawtucket show continual declines in population with all other communities showing increases. The greatest increases are expected in Lincoln with 23.4 between 1975 and 2020, and Sutton with 32.8 percent between 1975 and 2000. The Rhode Island communities still remain more densely settled.

<u>Future Floods</u> - In developing the flood picture of a river basin, consideration should be given to those flood which have occurred and to those floods which could occur in the future. The following paragraphs describe an intermediate regional flood and a



UNITED STATES POPULATION BY AGE
1970 AND 1990

Source: Statistical Abstract of the United States, 1973.

FIG. 1-21

TABLE 1-21

POPULATION PROJECTIONS 1990, 2000, 2020

	1975	1990	2000	2020	% Change	Pop. Density 2000
Millbury	12,121	13,500	14,000	N.A.	15.5	875
Sutton	4,969	6,150	6,600	N.A.	32.8	201
Grafton	10,630	11,300	11,700	N.A.	10.1	513
Northbridge	12,165	12,800	13,400	N.A.	10.2	779
Uxbridge	8,528	9,000	9,200	N.A.	7.9	311
Millville	1,744	1,850	1,950	N.A.	11.8	397
Blackstone	6,486	6,[illegible]00	7,100	N.A.	9.5	633
Cumberland	27,648	29,400	30,800	32,500	17.5	1,136
Lincoln	17,177	19,600	20,400	21,200	23.4	1,096
Central Falls	16,689	11,300	11,000	10,900	-34.7	9.166
Pawtucket	72,024	62,300	60,500	60,000	-16.7	6,875

Source for MA communities: Central Massachusetts Regional Planning Commission

Source for RI communities: Rhode Island Statwide Planning Program, Revised 19[illegible]

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PAWCATUCK RIVER AND NARRAGANSETT BAY DRAINAGE BASINS. WATER AND--ETC(U)

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standard project flood in the vicinity of Cumberland, Lincoln, Central Falls and Pawtucket, Rhode Island. A flood comparable to the standard project flood can reasonably be expected. The intermediate regional flood may be expected to occur more frequently but will not be as severe as the standard project flood.

Large floods have been experienced in the past on streams in the general geographical and physiographical region of the study area. Heavy storms similar to those causing these floods could occur over the watershed of the Blackstone River. In this event, floods would result on this stream comparable in size with those experienced on neighboring streams. It is therefore desirable, in connection with any determination of future floods which may occur on the Blackstone River, to consider storms and floods that have occurred in the region on watersheds whose topography, watershed cover and physical characteristics are similar to those of this stream.

Future Economy - SENE projections of economic activity in southeastern New England predict an overall continuation of the basic decline in the proportionate importance of manufacturing, with the exception of machinery, fabricated metals and ordinance, and transportation equipment; growth in the financial and government sector; and substantial growth in services. In the Worcester-Fitchburg-Leominster SENE subarea, manufacturing is expected to decline from a 45.3 percent share of that region's total earnings in 1969 to 37.3 percent in 1990 and 31.4 percent in 2020. At the same time, the service industries are expected to grow in their share of total earnings from 13.9 percent in 1969 to 17.4 percent in 1990 and 20.3 percent in 2020, mostly in the city of Worcester itself, which is becoming a service center for the expanding western fringe of the Boston metropolitan area in spite of the influence of Boston as regional center for government finance, communication and service activities. The Fitchburg-Leominster portion of this subarea is significantly more manufacturing based than the city of Worcester itself, and is expected to remain so.

Similarly, in the Providence-Pawtucket-Warwick subarea, SENE predicts manufacturing's share of earnings will decline from 36.9 percent in 1969 to 31.1 percent in 1990 and 27.2 percent in 2020, while services grow from 15.0 percent to 17.2 and 19.0 percent for the same periods. Growth is also projected for wholesale and retail trade and government, relative to other industries.

When just the industries making up the basic or export segment of the area economy (i.e. those who sell goods or services

to consumers outside the region) are examined, the shift to a service based economy is less evident, especially in the Worcester area. Table 1-22, SENE Forecasts of Industry Share of Regional Export Earnings 1959-1990, indicates each industry's share of total export earnings. Manufacturing industries accounted for nearly 100 percent of the Worcester-Fitchburg-Leominster (WFL) subarea's export base in 1959 and 96 percent of the Providence-Pawtucket-Warwick (PPW) subarea base for the same year. By 1990, SENE expects that manufacturing will still comprise about 96 percent of the WFL export earnings and about 80 percent of the PPW export earnings.

Of the manufacturing industries in Table 1-22 (Regional Export Earnings), miscellaneous manufacturing (primarily jewelry) shows promise for substantial growth while the metal working and machinery industries, although losing in their share of total export earnings, still make up a large share of manufacturing earnings. The textile mill products exhibit substantial decline in regional importance.

The economic character of the region surrounding the Blackstone Valley appears likely to be altered in the future as a result of recent or impending large scale economic changes resulting from the energy crisis, dollar devaluation, restructuring of the northeastern Unites States railroad system, the closing or reduced activity of most military bases in the region, the possible development of oil and/or gas resources on Georges Bank, and the trends toward ever larger bulk carriers for ocean shipping. The net result of all these changes, together with the need for substantially more jobs, is difficult to appraise, especially toward energy importance and consequently toward foreign trade in general.

Overall, the total picture appears to lead toward more diversity in the region's manufacturing. If foreign policy tends toward trade expansion, the unique deep-draft capability of Narragansett Bay would add to the importance of the Blackstone Valley, as one of the best rail routes to Narragansett Bay from the interior of the Nation. All these changes indicate substantial demand for industrial, warehousing and transportation land in the region surrounding the Blackstone.

The effects of the predicted industrial growth mix on the economic well being of the watershed's inhabitants can be measured in the personal income those industries are expected to return. Figure 1-22, Total Personal Income, 1950 to 2020, shows that according to the SENE study, the economy of the two subareas comprising the Blackstone Valley is expected to expand at a rate

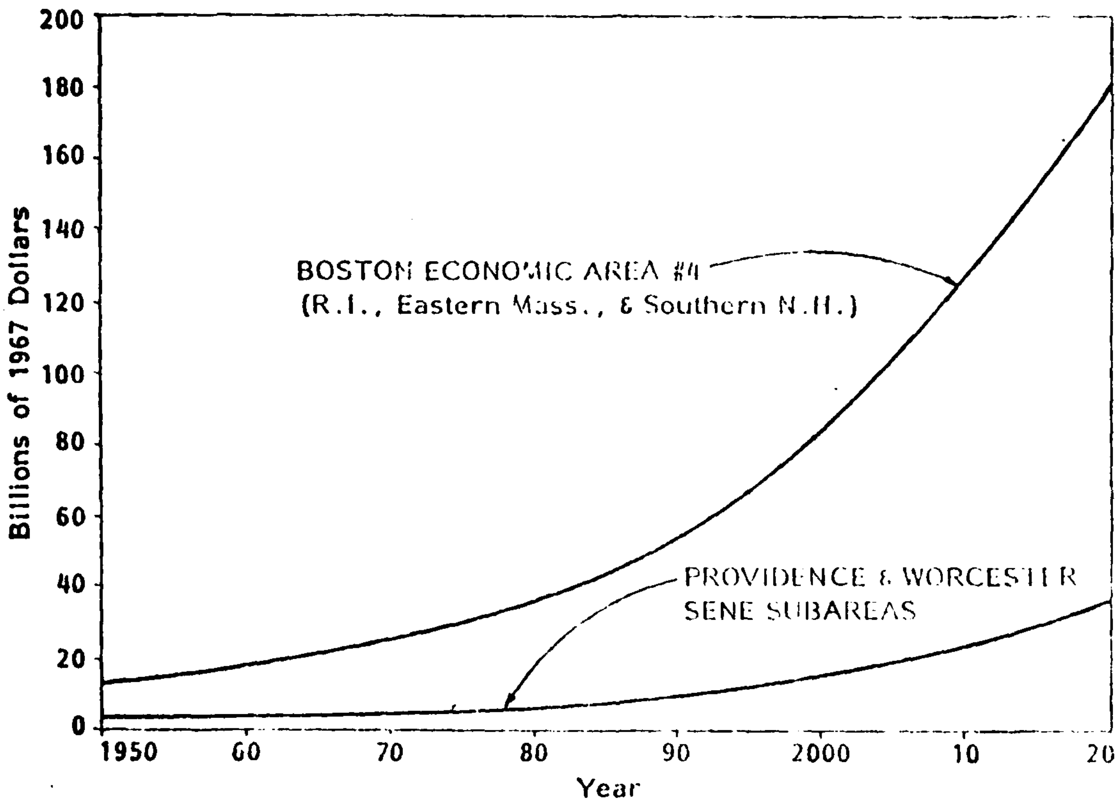
TABLE 1-22

SENE FORECASTS OF INDUSTRY SHARE
OF REGIONAL EXPORT EARNINGS
1959 - 1990

Selected Industry	1959 % of Export Base Earnings	1959 Rank	1969 % of Export Base Earnings	1969 Rank	1990 % of Export Base Earnings	1990 Rank
Worcester-Fitchburg-Leominster Area						
Miscellaneous Manufacturing	32.4	1	29.4	1	32.3	1
Machinery, excl. Electric	28.8	2	28.1	2	25.0	2
Textile Mill Products	10.6	3	5.5	5	1.8	10
Primary Metals	10.0	4	7.7	4	5.0	5
Paper & Allied Products	D	5	D	6	D	8
Fabricated Metals & Ordnance	5.0	6	11.5	3	13.3	3
Lumber & Furniture	4.9	7	4.0	7	2.3	9
Apparel & Other Textiles	1.1	8	-	-	-	-
Printing & Publishing	.4	9	2.0	10	3.8	7
Professional Services	-	-	4.0	8	8.8	4
Utilities (Elect, Gas, San.)	-	-	3.1	9	4.1	6
Providence-Pawtucket-Warwick Area						
Miscellaneous Manufacturing	43.3	1	54.5	1	61.2	1
Textile Mill Products	36.8	2	22.3	2	12.6	2
Primary Metals	6.4	3	4.2	5	2.6	6
Machinery, excl. Electric	5.3	4	.3	10	-	-
Fabricated Metals & Ordnance	4.6	5	4.5	4	.6	11
Utilities (Elec, Gas, San.)	1.4	6	1.1	9	1.2	10
Finance, Insurance & Real Estate	1.3	7	2.1	7	2.5	9
Trucking & Warehousing	.4	8	.1	12	.6	12
Communications	.4	9	.3	11	-	-
Forestry & Fisheries	-	10	-	-	-	-
Professional Services	-	-	6.4	3	2.6	7
Wholesale & Retail Trade	-	-	2.6	6	6.7	3
Printing & Publishing	-	-	1.6	8	2.5	8
Contract Construction	-	-	-	-	3.5	4
State & Local Government	-	-	-	-	3.4	5

D=Deleted to avoid disclosure of confidential data

Source: "Southeastern New England Study of Water & Related Land Resources", NERBC, 1973, Appendix Table 12



TOTAL PERSONAL INCOME
1950 TO 2020

SOURCE: "Southeastern New England Study of Water and Related Land Resources", Interim Report - New England River Basins Commission, March, 1973

Fig. 1-2?

significantly slower than the southeastern New England region as a whole.

The per capita personal income of the watershed's inhabitants will apparently converge toward the per capita income level for the Nation:

	Per Capita Personal Income							
	1950		1969		1990		2020	
	Amt	Index	Amt	Index	Amt	Index	Amt	Index
United States	2,065	1.00	3,416	1.00	6,166	1.00	14,260	1.00
BEA* Econ. Area #4	2,231	1.08	3,696	1.08	6,482	1.05	14,520	1.02
Worc. SENE Subarea	2,245	1.09	3,352	0.98	6,122	0.99	14,128	0.99
Prov. SENE Subarea	2,291	1.11	3,515	1.03	6,281	1.02	14,518	1.02

*BEA - Burea of Economic Analysis

The southeastern New England region (BEA Economic Area #4) is expected to decline in its per capita income relative to the U.S. from 8 percent higher than the U.S. figure in 1950 and 1969 to only 2 percent higher in 2020. The Providence subarea also has enjoyed a per capita income higher than the Nation's (11 percent higher in 1950) but is also converging toward the U.S. total. Per capita income in the Worcester subarea is expected to continue at one to two percent lower than that of the Nation.

Future Development- The imminent demographic and economic changes described above can be expected to create substantial demand for the development of land in the Blackstone region. It will be shown that the best soil conditions for urban and industrial development and for on site water and sewage disposal lie close to the river. In addition a major rail line lies along its banks, and good highway access is not far away. As a result, new growth within the basin can be expected to be disproportionately concentrated along the river making both its control and the development of its water resources far more important for the future than for the present.

In a recent study financed and administered by the Rhode Island and Massachusetts Departments of Environmental Management and by the Rhode Island and Massachusetts Historic Commissions the feasibility of developing a linear park system along the Blackstone River was investigated. It is hoped that the development of a river/canal park system for recreational purposes would serve the needs of an urban population, preserve the early industrial history of the valley, retain the natural beauty, and enhance the character and economic well-being of the communities along the river.

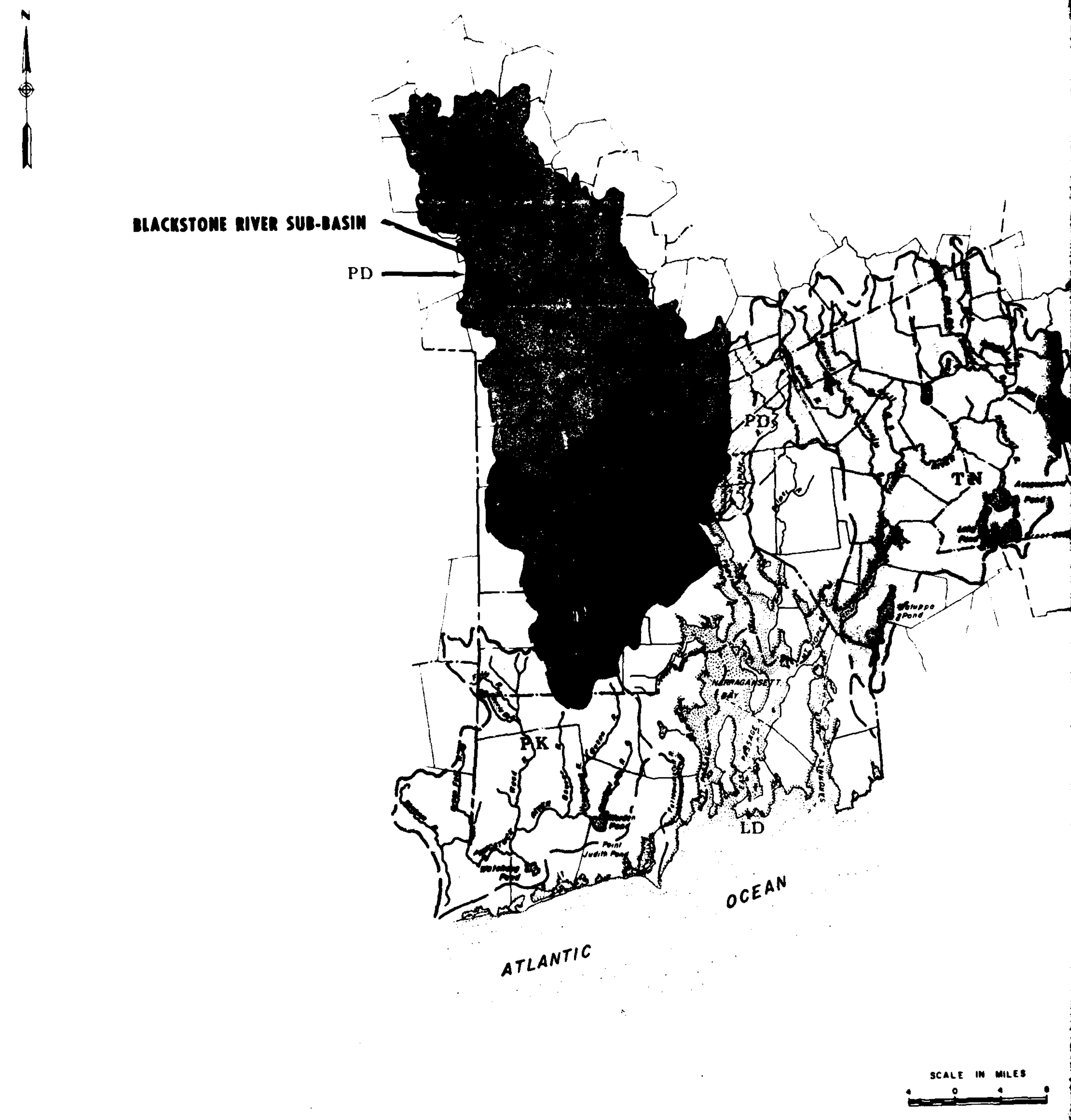
Summary of the Socio-Economic Outlook - The prospects for economic growth within the Blackstone Valley appear to be very different for the areas already substantially urbanized, the suburban fringe areas, and the nonurbanized areas of the watershed. The basic nature of the growth in these areas is a function of the future industrial mix of the region, which appears to be difficult to appraise in anything other than a speculative manner in light of the state of general flux in national economic and environmental policies and attitudes.

Growth in the small metal components industries traditional to the region is expected to occur within and at the fringes of the urbanized area because of their relatively small demands on land and water resources and greater demand for skilled labor.

On the other hand, the prospect for materials processing industries gaining a substantial share of the region's resources and generating an even greater share of the region's earnings is very real. The greatest prospects are for the development of petrochemical industries as the oil refining capacity of the region increases substantially and for warehouse-transfer industries as the unique deep-draft bulk shipping capabilities of Narragansett Bay are developed. The site requirements for these industries are markedly different from traditional regional industries as they are likely to need individual sites of much greater relative size, large scale rail transfer points and large volumes of process water. In short, these industries seem ideally suited for the wide sand and gravel terraces along the middle reaches of the river which are predominantly rural in their character today.

The outlook then, is that certain portions of the Blackstone Valley, especially lands close to the river, can be expected to become substantially urbanized over the next decade, 1975 to 1985, barring a major war or depression. Land uses expected along the river will probably include substantial industrial, warehousing and transportation activities of regional and, possibly, national economic importance.

The impact of this on the allocation of population throughout the region could be substantial. There is little doubt that the suburban fringes will continue to grow at substantial rates, but given the growing cost of travel and the resulting desire of people to be close to their jobs, industrial development of the rural middle reaches of the river could very well lead to rapid "suburbanization" of those lands. Again, this development is likely to stay close to the river for good well water supply and sewage leaching because of the difficulty in developing the glacial tills of the surrounding hillsides.



N
BLACKSTONE RIVER SUB-BASIN
PD
PD
TN
PK
LD
NARRAGANSETT BAY
Point Judith Pond
OCEAN
ATLANTIC
SCALE IN MILES
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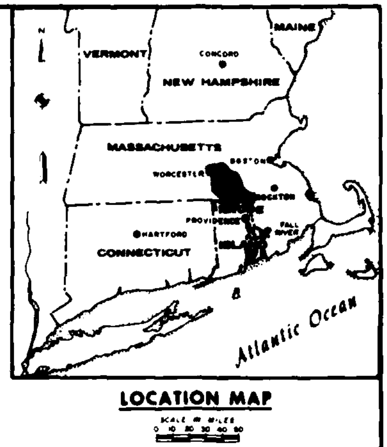
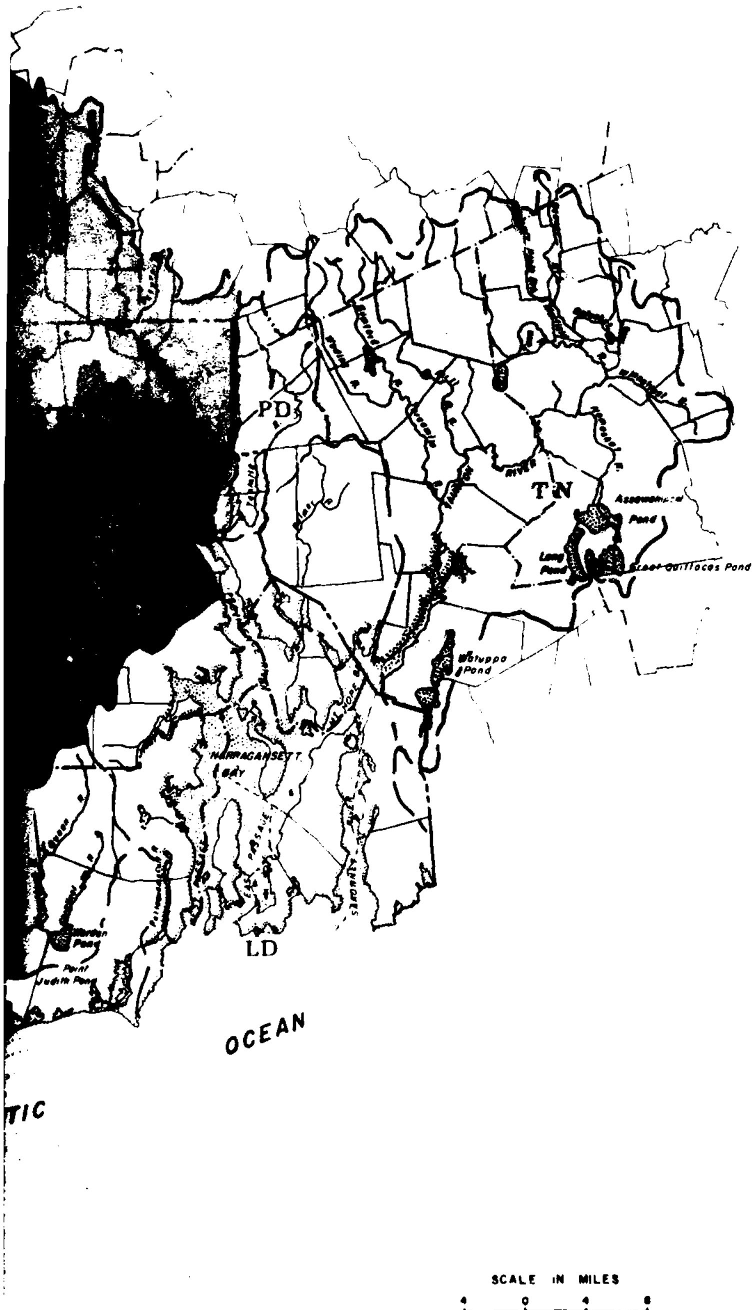


LOCATION MAP



LEGEND

———	COMMUNITY BOUNDARY
— — —	COUNTY BOUNDARY
—-·—-	STATE LINE
( )	RESPECTIVE BASIN LIMITS
PX	PAWTUXET RIVER BASIN
TN	TAUNTON RIVER BASIN
PK	PAWCATUCK RIVER BASIN
LD	LOCAL DRAINAGE
PD	PROVIDENCE RIVER GROUP WATERSHED
PD_1	WOONASQUATUCKET - MOSHASSUCK - PROVIDENCE RIVERS SUB-BASIN
PD_2	BLACKSTONE RIVER SUB-BASIN
PD_3	TENMILE - SEEKONK RIVERS SUB-BASIN

WATER RESOURCES MANAGEMENT REPORT

PAWCATUCK RIVER AND NARRAGANSETT BAY STUDY

BASIN MAP

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1

1

2

APPENDIX 2

PLAN FORMULATION

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FORMULATING A PLAN

The primary objective of this study is to provide, within established water resources guidelines, a flood control management program to eliminate or minimize flood losses in flood prone areas. The study employed a comprehensive approach toward developing a plan to solve basin flood problems, giving full consideration to wise utilization of basin water and related land resources.

FORMULATION AND EVALUATION CRITERIA

In evaluating possible solutions to the flood management problems of the area, selection of a plan involved technical, economical and social criteria including consideration of all beneficial and detrimental effects on the environment. Supplemental criteria, while it was not studied as intensely, involved acceptability, completeness, effectiveness, equity, irreversible effects and ease of maintenance and operation. Inclusion of these factors assured the selection of a plan of improvement which represents an acceptable and justifiable solution that best responds to the problems and needs of the area.

Economic Criteria - The derivation of potential for the various flood control strategies examined followed certain economic guidelines. Monetary benefits were qualified solely for the future avoidance of damage due to flooding. While water supply potential was examined in the analysis of reservoir sites, only costs attributable to flood control were used as a guide for screening projects with favorable benefit/cost ratios. The assumption was that the separable cost of flood control construction must be effective in and of itself.

Flood control benefits were projected based on damage cost data gathered by the Corps of Engineers. Direct and indirect costs were determined through field surveys. Except for local protection projects, all damage data for this study were aggregated by town and by land use.

Prevailing price levels on or about June 1976 were used as the base for calculating all benefits and costs during the early plan formulation phase. Benefit/cost ratios were calculated on an annual charge basis. Federal construction costs were converted to annual charges using current discount interest rates for projects evaluated over their expected useful life. In Appendix 7, Economics, annual charges and benefits for economically feasible plans were updated using June 1981 prices with a discount interest rate of 7-3/8 percent.

Technical Criteria - Technical criteria were adopted from appropriate engineering regulations, manuals, pamphlets and technical letters and supplemented by engineering judgment and technical experience. Basically, the selected plan had to be technically feasibile, complete within itself, in need of no additional future improvements and an insurance against significant worsening of any flood conditions. Where practical, the

alternative measures considered for urban areas were formulated in accordance with Engineering Circular 1105-2-47, which stipulates that the standard project flood is an appropriate level of protection for high dikes and floodwalls in urban areas. It also states that if the standard project flood protection is unjustified or only marginally justified, the level of protection may be reduced to yield a more economically feasible plan by utilizing alternative flood damage reduction measures. However, reductions in the level of protection below the standard project flood are to be avoided whenever possible.

Environmental and Social Criteria - Environmental and social criteria utilized in considering the environmental quality objective and the social well-being and regional development accounts included the following requirements of the National Environmental Policy Act of 1969 (Public Law 91-190):

- Analysis of the environmental impact of any proposed action;
- Identification of any adverse environmental effects which could be avoided should the proposal be implemented;
- Evaluation of alternatives to the proposed action;
- Determination of the relationship between local short term uses of man's environment and the maintenance and enhancement of long term productivity; and
- Accounting of any irreversible and irretrievable commitments of natural resources and biological systems which would be involved in the proposed action should it be implemented.

In order to attain the environmental objectives as specified in the Principles and Standards, the following factors were also considered:

- Management, protection, enhancement or creation of areas of natural beauty and human enjoyment;
- Management, preservation or enhancement of particularly valuable or outstanding archaeological, historical, biological and geological resources and ecological systems;
- Enhancement of quality aspects of water, land and air, but at the same time recognizing and planning for the need to harmonize conservation of resources with the land use objectives of economic use and development; and
- Development and use of objectives which minimize or preclude the possibility of undesirable and irreversible changes in the natural environment.

As mandated by Section 122 of the River and Harbor Act of 1970, adverse economic, social and environmental effects of proposed projects received full consideration and included the following:

- Effect of air quality, noise levels and water pollution;
- Destruction or disruption of man-made and natural resources;

- Aesthetic values, community cohesion, and the availability of public facilities and services;
- Adverse employment effects and tax and property value losses;
- Injurious displacement of people and businesses;
- Disruption of desirable community and regional growth; and
- Public acceptance of proposed improvements and ability and willingness to meet local cooperation requirements.

These environmental and social factors formed part of the basis for evaluating alternatives, corrective measures for the study area.

POSSIBLE SOLUTIONS

In formulating alternative measures a whole array of regulatory and corrective measures, including a Without Condition was considered. These measures were compared to the base condition using the criteria of economic efficiency, environmental enhancement and social well-being and were evaluated as acting either independently or supplementing one another. These measures are listed in Table 2-1. The following paragraphs briefly describe each measure and the rationale used during the screening processes. Detailed descriptions are provided later in this section for those measures which passed preliminary screening and were further evaluated.

Without Condition - The flood plains, long popular among developers, may continue to provide sites for occasional construction until existing Federal and State regulations are fully enforced. For the purpose of this report, under the Without Condition it is assumed that local interests would institute successful programs for controlling growth within the flood plains and would participate in the National Flood Insurance Program.

By declining to participate in the National Flood Insurance Program, communities flood prone developments become ineligible to receive any Federal funds. Furthermore, as ownership of properties located in the flood plain is transferred (as defined by the Federal Emergency Management Administration, (FEMA), new homeowners desiring financing from any Federally insured lending institution must first obtain flood insurance. According to law, if the necessary insurance coverage is not obtained such a mortgage cannot be advanced to the prospective buyer.

However, by enrolling in the flood insurance program and enacting the local land use control measures it requires, the Without Condition would provide economic protection against physical losses for events up to a 100-year frequency flood. The Without Condition is the most probable future conditions likely to occur in the absence of any Federal action resulting from this study.

TABLE 2-1

POSSIBLE SOLUTIONS

WITHOUT CONDITION PROFILE
(See Text for Definition)

1. National Flood Insurance Program

REGULATORY MEASURES

1. Flood Plain Regulations

    a. Encroachment Lines
    b. Zoning
    c. Subdivision Regulations

2. Land Use Programs

3. Other Regulatory Measures

    a. Building Codes
    b. Urban Redevelopment
    c. Tax Adjustments
    d. Warning Signs
    e. Health and Fire Regulations
    f. Cleanup Campaign
    g. Flood Forecasting
    h. Evacuation

GENERAL CORRECTIVE MEASURES

1. Reservoirs

2. Walls and Dikes

3. Reservoir Management Programs

4. Hurricane Barriers

5. Stream Improvements

6. Floodproofing

Regulatory Measures - Regulatory measures do not reduce, eliminate or prevent flooding but instead they regulate or discourage the use and development of the flood plains, thus lessening the threat of flood damage and possible loss of life. Several regulatory measures which are non-structurally oriented and could be applied to this watershed are described in the following paragraphs:

National Flood Insurance Program - This program was established under the National Flood Insurance Act of 1968, expanded in the Flood Disaster Protection Act of 1973, and broadened and modified since then. It was specifically designed to provide limited amounts of flood insurance, previously unavailable from private insurers, to property owners by means of a Federal subsidy. In return for this subsidy, the Act requires that State and local governments adopt and enforce land use and control measures that will restrict future development in flood prone areas in order to avoid or reduce future flood damages. These measures include flood plain zoning, careful siting and drainage preparations, special construcition practices and building materials, special treatment of sewage disposal systems and elevation of the first floor above the level of the 100-year flood or in the case of commercial and industrial development, floodproofing to this elevation. Flood insurance is available through local insurance agents only after a community applies and is declared eligible by the Federal Insurance and Hazard Mitigation Office of Federal Emergency Management Administration (FEMA).

Flood Plain Regulations - These are considered to be the most effective nonstructural means of alleviating or reducing flood damages. They can prevent additional construction on already developed flood plains and can be a compelling force in avoiding a repetition of past building errors. They may be more restrictive than the land use control measures required for participation in the National Flood Insurance Program.

These restrictions require the enactment of ordinances as legal tools to implement and enforce detailed plans resulting from land use planning programs. The programs usually involve the preparation of maps and profiles which delineate the flood hazard areas. These are normally provided by Federal agencies or consultant firms so that zoning can be established by the local community.

To fully explain their importance, the flood plain regulations have been classified into three major categories and are explained as follows:

a. Encroachment Lines - These are the lateral limits, represented as lines drawn on a detailed map, along each side of the watercourse or body of water that are required to preserve the flood carrying capacity of the stream, as well as to assure attainment of the basic objective of precluding further growth within the flood plains. The key zone which should be void of obstructions is the floodway area (stream channel and portion of the flood plain) required to pass a large flood. The selection of the floodway, as defined by FEMA, is based on the principle that the

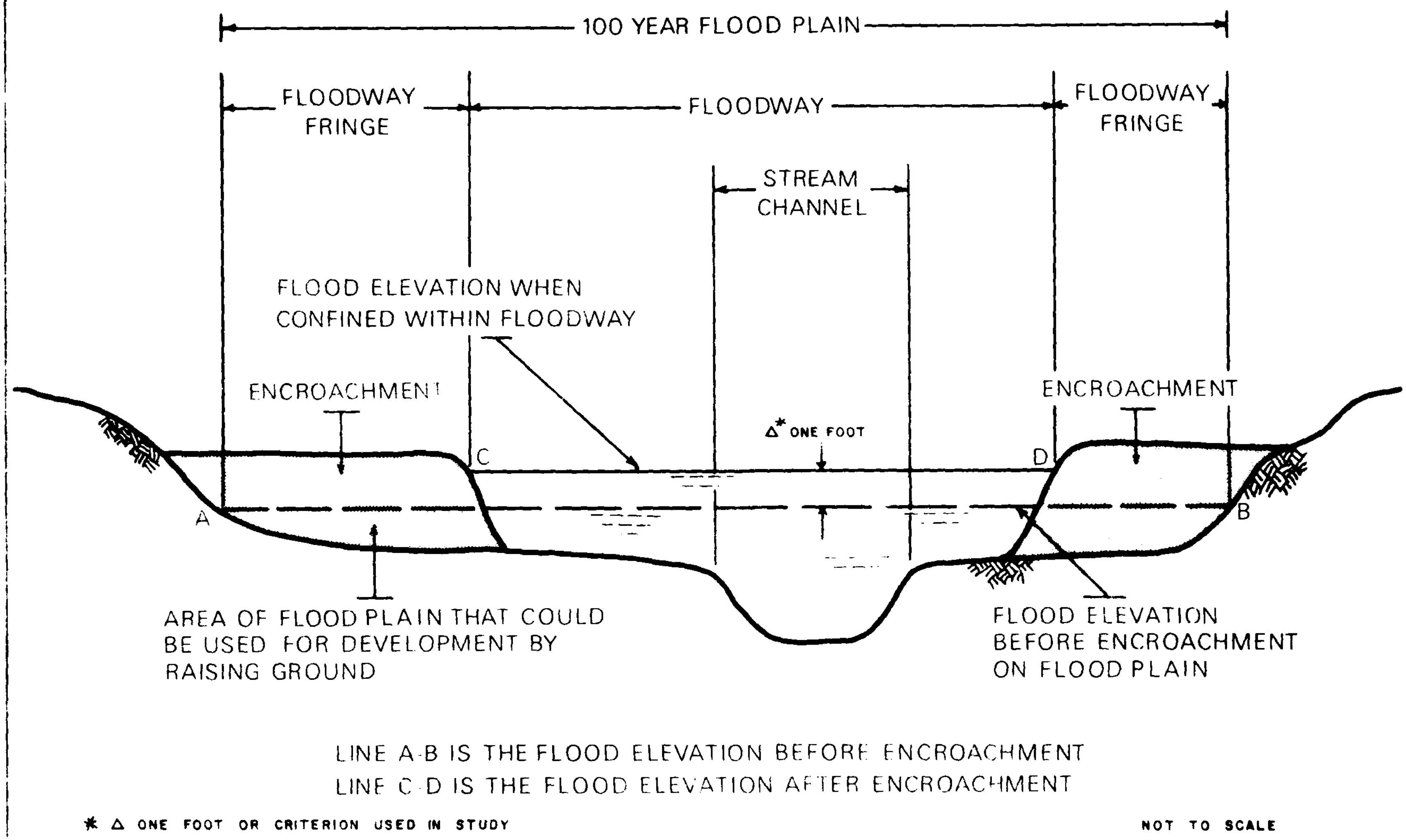
area chosen for the floodway must be designed to carry the waters of the 100-year flood (an event having a one percent chance of occurring or being exceeded in any one year) without increasing the water surface elevation of that flood more than one foot at any point. Figure 2-1 shows a schematic presentation of the floodway concept.

Within the floodway, no construction or filling should be permitted but the removal of flood prone structures, dams or bridges is permissible. Certain nonstructural uses such as parking lots, recreational facilities and agricultural uses may be allowed. Generally this would apply to future development as it is impractical to enforce such a policy on existing development. Adherence to this policy would lessen potential flood losses as the floodway would remain in a free flowing state.

The floodway fringe area consists of the two strip areas along the lateral limits of the selected floodway (usually the 100-year flood). Encroachment or filling of the fringe area may be permitted to the degree that it will not cause the water surface of the 100-year flood to rise more than one foot (or less if so established by State or local regulations) or cause excessive velocities. Although construction of nonresidential structures is allowed under the FEMA policy, it is discouraged due to high flood insurance rates. However, should any construction be instituted, floodproofing to the 100-year levels is required in accordance with the standards contained in the Corps of Engineers Engineering Pamphlet 1165-2-314, "Flood-proofing Regulations."

b. <u>Zoning</u> - Zoning is a legal measure that State, county or local governmental agencies can implement and enforce to effectively reduce the flood damage potential of an area in accordance with a planned program of development and land use. Zoning ordinances can designate the channel and those portions of the adjoining flood plain required for passage of floodwater in accordance with the degree of flood protection desired. Development could be permitted in the fringe areas of the flood plain where water is ponded, provided that adequate measures were taken to reduce the potential damage consistent with the risk involved and also provided that no additional flooding or damages occur elsewhere as a result of development. These flooded areas may be zoned for different types of development such as residential, commercial, agricultural, recreational or open space. Zoning measures insure the safekeeping of property for the health, welfare and safety of the general public. Effective zoning requires enforcement of the zoning bylaws, which in turn requires that each bylaw be clear, concise and thorough. Table 2-2 shows an overview of flood plain zoning.

c. <u>Subdivision Regulations</u> - Subdivision regulations are used by local governments to specify the manner in which land may be divided for planned building development. Regulations can be adopted that state requirements for street widths and minimum elevations, drainage structures, minimum building elevations, size lots and restrictions on location to provide adequate waterways for passage of floodflows, minimizing flood damages.



DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

FLOODWAY SCHEMATIC

Fig. 2-1

TABLE 2-2

OVERVIEW: FLOOD PLAIN ZONING

Purposes	Regulatory Standards	Advantages	Limitations
1. Protect public safety and prevent nuisances by prohibiting dangerous uses (e.g., chemical factories in flood hazard areas), unreasonable increases in flood heights due to floodway encroachments, and threats to safety by location of quasi-public uses such as motels in flash-flood areas.	1. Delineate floodway areas and prohibit new structural uses and land alterations which will *individually or cumulatively* increase flood *heights or* velocities beyond defined levels.	1. The major tool of *comprehensive planning* to promote the most suitable use of lands throughout a community.	1. *May "take"* private property if too restrictive.
2. Promote most suitable and economic use of community lands as a whole by implementing comprehensive land use plans allocating flood plain areas to uses consistent with the flooding threat.	2. Establish flood protection elevations and protection standards for floodway and flood fringe areas and uses.	2. Can incorporate wide range of provisions relating to flood plain *management* and other objectives.	2. Does not regulate sale or transfer of lands.
3. *Reduce the cost of* public facilities and assist in the implementation of facility plans for roads, sewer, water, schools, etc. by preventing or limiting the type and density of development in flood hazard areas.	3. In some instances, abate existing floodway uses of a nuisance nature and require floodproofing with major alteration of flood fringe uses.	3. *Can* separate flood *areas* into zones depending upon flood hazard and apply varying standards to the zones.	3. Often weakened by irrational variances and exceptions.
	4. Divide flood fringe into commercial, residential and industrial flood fringe zones, and other districts with specifications designed to reduce conflicts between uses and promote the general welfare.	4. Most useful tool in preserving floodway areas.	4. Is largely prospective in nature *(applies only to new uses)* and usually unsuccessful when applied to high-value, nonnuisance existing uses.
		5. Can be applied (in some areas) to existing uses with a nuisance character.	5. Usually does not incorporate detailed building design standards.
			6. Many states require prior comprehensive, community-wide planning although this requirement *has not* been strictly enforced.

Effective subdivision regulations can benefit public health and welfare and also reduce municipal costs such as maintenance of street and utilities during flood periods. Subdivision regulations are generally a means of controlling construction in undeveloped flood plain areas. The following provisions can be added to the regulations of a community to help prevent flood damage:

- Require the location of flood prone areas to be shown on master maps;
- Delineate floodway limits or encroachment lines;
- Prohibit encroachment in floodway or flood hazard areas;
- Require placement of streets and public utilities above a selected flood level;
- Provide safe building elevations on lots above selected floor heights by means of full or open structural support; and
- Require installation of adequate drainage facilities.

Land Use Programs - Conservation, scenic or flood control restrictions or easements may be required for floodway or flood hazard areas where little or no development is desirable. Land use restrictions can be used to prevent development that would be incompatible with public objectives while allowing continued private ownership of the land. Certain future land use rights such as construction of buildings that are not consistent with good flood plain management could be purchased from existing landowners. Permitted existing uses could be farming, wildlife, recreation parks and woodland. Land use restrictions may also result in a lowering of the landowner's tax assessment. Table 2-3 shows an overview of flood plain subdivision regulations.

Other Regulatory Measures - Other measures that can be effective in lessening the threat of flood losses and possible loss of life are described as follows:

a. Building Codes - The primary purpose of building codes is to set minimum standards for controlling the design, construction and quality of materials used in buildings and structures within a given area so that life, health, property and public welfare are safeguarded. Because it may be impractical to prevent building in all areas subject to flooding, building codes and/or regulations can be used to minimize structural and subsequent damages resulting from inundation. Local governmental agencies should adopt building restriction codes and regulations that would assist in reducing future flood damages. These would set forth standards for the construction of buildings that can:

- Prevent flotation of buildings from their foundations by specifying adequate anchorage;
- Establish basement elevations and minimum first floor elevations consistent with potential flood occurences;

TABLE 2-3

OVERVIEW: FLOOD PLAIN SUBDIVISION REGULATION

Purposes	Regulatory Standards	Advantages	Limitations
1. Prevent victimization and fraud due to sale of flood lands to innocent purchaser.	1. Prevent subdivision of land unsuitable for intended purposes.	1. In many states, may be made to apply extraterritorially for urbanizing areas.	1. Only indirectly controls use of land; must be in combination with zoning.
2. Protect floodway areas from encroachment by roads, buildings, etc.	2. Require that each building site have an area above flood elevation suitable for building purposes, on-site waste disposal (where applicable) and adequate access.	2. Very flexible in negotiating with developer.	2. Difficult to protect floodways unless they are identified on maps.
3. Insure that roads, sewers, water supply, and other subdivision services are located in areas above flood elevations or protected against flooding.	3. Require that flood hazard areas be noted on face of plat, and in some cases, the adoption of deed restrictions to control future uses in flood-prone areas.	3. In most states, does not require prior comprehensive planning although a street plan is often required.	3. Does not apply to structural design or materials for future structures on subdivision land.
4. Implement master and comprehensive plans including public facility components.	4. Require flood protection for sewer, water, and roads installed by subdivider.	4. Can be used to require developer to provide flood data on a case-by-case basis.	4. Applies, in many instances, only to new land sales and divisions.
5. Insure that subdivider installs drainage facilities which are consistent with community drainage system standards.	5. Require installation of drainage facilities or payment of fees in lieu of installation by subdivider.	5. Not as vulnerable to judicial attack as zoning.	5. "Loopholes" common in ordinances which permit subdividers to escape enforcement through "strawman" transactions (i.e., multiple divisions through friends, relatives).
	6. In some instances, require dedication of flood areas as parks or for other open space purposes by the subdivider.		

- Prohibit basements in those areas subject to shallow frequent flooding where filling and slab construction would virtually prevent all damage;
- Require building reinforcement to withstand water pressure or high velocity flow and restrict the use of materials which deteriorate rapidly in the presence of water;
- Prohibit equipment, chemical storage, boilers and electric equipment, for example, that might be hazardous to life when submerged. Table 2-4 shows an overview of flood plain building codes.

b. Urban Redevelopment - Urban redevelopment gives communities an opportunity to relocate developments from flood plains to secure areas safe from floods and to ensure that new construction in the flood plains is designed to withstand flooding. Communities contemplating or actually planning urban redevelopment should avail themselves of appropriate technical assistance so they can enact proper and adequate zoning ordinances.

c. Tax Adjustments - Lowering the tax rate on land dedicated to agriculture, recreation, conservation or other open space uses is an effective tool in preserving existing flood plains or floodways along streams.

d. Warning Signs - A method which may be used to discourage development is the erection of flood warning signs in the flood plain area or the prominent posting of previous high water levels. These signs carry no enforcement, but simply serve to inform prospective buyers that a flood hazard exists.

Because warning signs could be subjected to continued acts of vandalism, other methods of informing and protecting potential buyers of the flood hazards could be implemented. One type of action is requiring that all potential sellers of tangible property obtain from the community an affidavit certifying the property to be reasonably free from flood hazards.

e. Health and Fire Regulations - Flood prone communities should set up a plan to insure that health and safety of citizens in the event of a flood. Regulatory measures considered reasonable for a flood emergency should include contingency plans for:

- Temporary evacuation of public and personal property and livestock from low-lying areas;
- Prevention of disease should water supplies become polluted and sanitation facilities become inoperative;

TABLE 2-4

OVERVIEW: FLOOD PLAIN BUILDING CODES

Purposes	Regulatory Standards	Advantages	Limitations
1. Protect public and private safety from structures which may collapse during flood. 2. Prevent nuisances from floating structures which may jam bridges, litter other lands, and add to the destructive force of flood flows. 3. Protect public facilities. 4. Prevent blighting, reduction in property values, decrease in tax revenues. 5. Protect buildings and contents from flood damage.	1. Require elevation of structures and utilities on fill, pilings, or by other means. 2. Alternatively, require structural floodproofing of buildings and utilities through special design and use of waterproof materials.	1. Applies to new structures. 2. Often sustained in court. 3. Can be adopted by reference in most states. 4. Simple adoption procedures.	1. Applies only to new uses. 2. Performance standard approaches require expertise in administration 3. Do not usually apply extraterritorially. 4. Must be used in combination with other tools to preserve floodway. 5. Often not properly enforced. 6. Detailed flood elevation data essential for operation of regulations. Flood velocities, flood duration, wave action, erosion problems and other types of "site specific" data required to design or evaluate proposals for structural flood-proofing.

- Accessibility of the flood area for fire fighting equipment as the fire hazard is greater than normal in flooded areas due to damaged electrical systems; and
- Emergency systems for reporting fires because the normal fire alarm system is likely to be damaged during flood periods.

f. Cleanup Campaign - Laws or ordinances to control the dumping that encroaches on flood prone areas and legal means for implementing an enforcible cleanup campaign and for a continuing surveillance program which could be instituted.

g. Flood Forecasting - With the advent of computer technology and advance weather forecasting by the National Weather Service of the National Oceanic and Atmospheric Administration, reliable, accurate and timely forecasts of potential flood producing storms can be a valuable asset in reducing property losses and saving lives.

h. Evacuation - Bearing in mind the "flashiness" of New England streams, communities should identify flood prone areas and institute plans for immediate evacuation when floods are forecast. Individuals and companies should incorporate emergency plans for total evacuation to areas of safe refuge and constantly update and organize the personnel who carry through such plans. Materials and equipment too cumbersome to move should be located in ares not susceptible to flooding. Items of stock and equipment that can easily be moved or would suffer little damage from inundation should be placed in areas of high flood risk.

Personnel and alternates designated to implement the evaculation plan must fully understand their assignments and be ready to act within the available advance time.

General Corrective Measures - Generally, the most practical and logical way to reduce or control floods and associated damages in heavily urbanized flood prone areas is to use corrective measures oriented to structural components. Highly urbanized flood prone areas with an existing flood threat usually find regulatory measures to be either extremely expensive to implement or of such a nature that the social and environmental impacts would have an adverse effect of irreversible magnitude on the people, its economy and the area as a whole.

Potential corrective measures evaluated during this study are briefly described in the following paragraphs:

Reservoirs - In New England these usually consisted of rolled earth and rockfilled structures for impounding uncontrolled floodwaters. They are generally located at strategic points within a watershed to provide flood protection to downstream communities. An important factor relating to reservoirs that should not be overlooked is their ability to satisfy other needs such as water supply and water oriented recreation. Such multiple objectives result in greater utilization of the available natural resources within a watershed.

Walls and Dikes - This approach usually involves a system or a combination of concrete floodwalls, earth-rockfilled dikes and appurtenant facilities for confining floodflows to the channel or floodway. These are generally referred to as local protection projects because they provide protection to localized, high risk flood prone areas.

Reservoir Management Programs - Under certain conditions and barring any legal constraints, restrictions or conflicts, some of the major existing water impoundments within a watershed can be regulated to provide flood control storage. A plan of operation sets the drawdown limits, time and rates so that downstream flood problems are not created and upstream water rights are considered. The object of reservoir regulation is to temporarily retard peak flow long enough to desynchronize tributary flows from the flood peaks on the major rivers, before releasing those flows at controlled rates as the flood danger passes.

Hurricane Barriers - This type of measure can help prevent losses caused by tidal flooding. It would consist of a system of dikes and walls and jetties, together with gates and pumping facilities located at a strategic point, that prevent high tides from intruding along the inland waterway.

Stream Improvements - Where substantial flood damage can be attributed to the deterioration or neglect of the waterways, a rehabilitation program for improving channel conditions to increase their hydraulic efficiency and subsequent flood carrying capacity can generally be accomplished by the following measures:

a. To alleviate frequent flooding and subsequent flood losses, various methods of channel restoration work could include:

- Possible elimination of abrupt turns and oxbows;
- Widening and deepening of certain stretches of river;
- Improvement of waterway areas at bridges and culverts;
- Selective planting and/or revetment works for alleviating erosion problems;
- Removal of overhanging or uprooted trees and accumulated debris at critical points.

b. Improving channels in restricted pondage areas by modification or removal of dams can also offer some flood relief to critically high risk flood prone areas, providing proper measures are taken to prevent excessive scour and siltations.

c. The diversion of floodflows as a means of bypassing heavily congested flood prone areas can provide an adequate to high degree of flood protection while minimizing the social and environmental impacts.

Floodproofing - This measure is employed to render buildings and contents in flood hazard areas less vulnerable to flood damages. The techniques include:

a. Permanent measures such as:

- Waterproofing of basement and/or foundation walls;
- Installation of subsurface drain system with pumping facilities and where applicable, anchorage and reinforcement of floors and walls and use of water resistant interior materials;
- Raising the elevation of the structure;
- Valving off or termination of entering utilities;
- Continuation of internal building utility systems;
- Protection for immovable equipment;
- Bricking off windows and relocation of entrances; and
- Plans for removal of stock, emergency protection measures and a procedure for implementating floodproofing.

b. Contingency measures which require action to be taken to make them effective such as manually closed sewer valves and removable bulkheads for windows, doors and vents.

c. Emergency measures such as sandbagging, pumping and removal of contents to higher elevations that are carried out during floods according to prior emergency plans.

d. Permanent evacuation of developed areas subject to inundation accomplished by land acquisition and involving removal of structures and relocation of the population from such areas. These lands could then be returned to a natural habitat or used for agriculture, public parks, or playground, or other purposes consistent with flood management objectives.

As an alternative measure in specific cases, the temporary evacuation of persons and personal property could also be accomplished when a flood threat exists. This type of solution becomes more effective when combined with a reliable flood forecasting system.

Floodproofing standards applied through building codes and regulations to flood plain structures can permit economic development in the lower risk areas by restricting flood damages and other adverse effects to acceptable limits. Floodproofing requires adjustment both to structures and to building contents and involves keeping water out as well as reducing the effects of water entry. Such adjustments can be applied by the individual or as part of collective action either when buildings are under construction or during remodeling or expansion of existing structures. They may be permanent or temporary.

Floodproofing, like other methods of adjusting to floods, has its limitations. In addition to reducing loss potentials, a main purpose of floodproofing habitable structures is to provide for early return to normalcy after floods have receded rather than for continuity of occupancy. Through a false sense of security, occupants sometimes choose to remain during a flood and risk being stranded or losing their lives. Only very substantial and self-contained structures should be occupied

during a flood. Unless correctly use, floodproofing can tend to increase uneconomical use of flood plains. If applied to structurally unsound buildings (i.e., closures and seals), it can result in more damage than would occur without floodproofing. It is usually applied to individual structures, but unless floodproofing is also applied to entrance ways, it is only partially effective in an area context. Accordingly, access ways should be passable at least in floods up to the magnitude used in setting floodproofing elevations.

ALTERNATIVES CONSIDERED IN EARLIER STUDIES

Corrective Measures - On the basis of studies done in the past many potential areas were eliminated either by inspection, low benefit/cost ratios or nonfeasibility.

It should be noted that the following measures were judged on their own merit at this stage of the analysis, with each measure considered independently. Only those which provided an adequate, realistic and practical engineering solution and were socially and environmentally acceptable and economically justified were reserved for more detailed consideration.

As the roles of the Without Condition and all regulatory measures are oriented to fulfilling projected needs and to establishing appropriate measures for preventing or minimizing future flood problems, their importance for further evaluation, particularly as a supplement to corrective measures, merits consideration. Consequently, both programs were retained for further analysis in all study areas.

The following corrective measures were analyzed as independent components for solving specific flood control problems and needs pertaining to the basin (See Basin Map, Plate D-1):

Reservoirs - Within the study area, numerous reservoir sites were originally investigated to alleviate flooding and also to satisfy other needs. Due to the limited degree of protection that reservoirs could provide to existing damage areas, the many engineering, social and environmental constraints and the findings that costs would far exceed accrued benefits, most of the reservoir sites considered were eliminated from further evaluation. Results of this preliminary analysis indicated, however, that three reservoir sites warranted further investigation, either as single-purpose flood control projects or as multipurpose projects. Three reservoirs are located at strategic points which would provide the greatest amount of flood protection. They are the Lackey Reservoir located in Douglas, Massachusetts and the Nipmuc or its alternate, Mapleville, in Burrillville, Rhode Island.

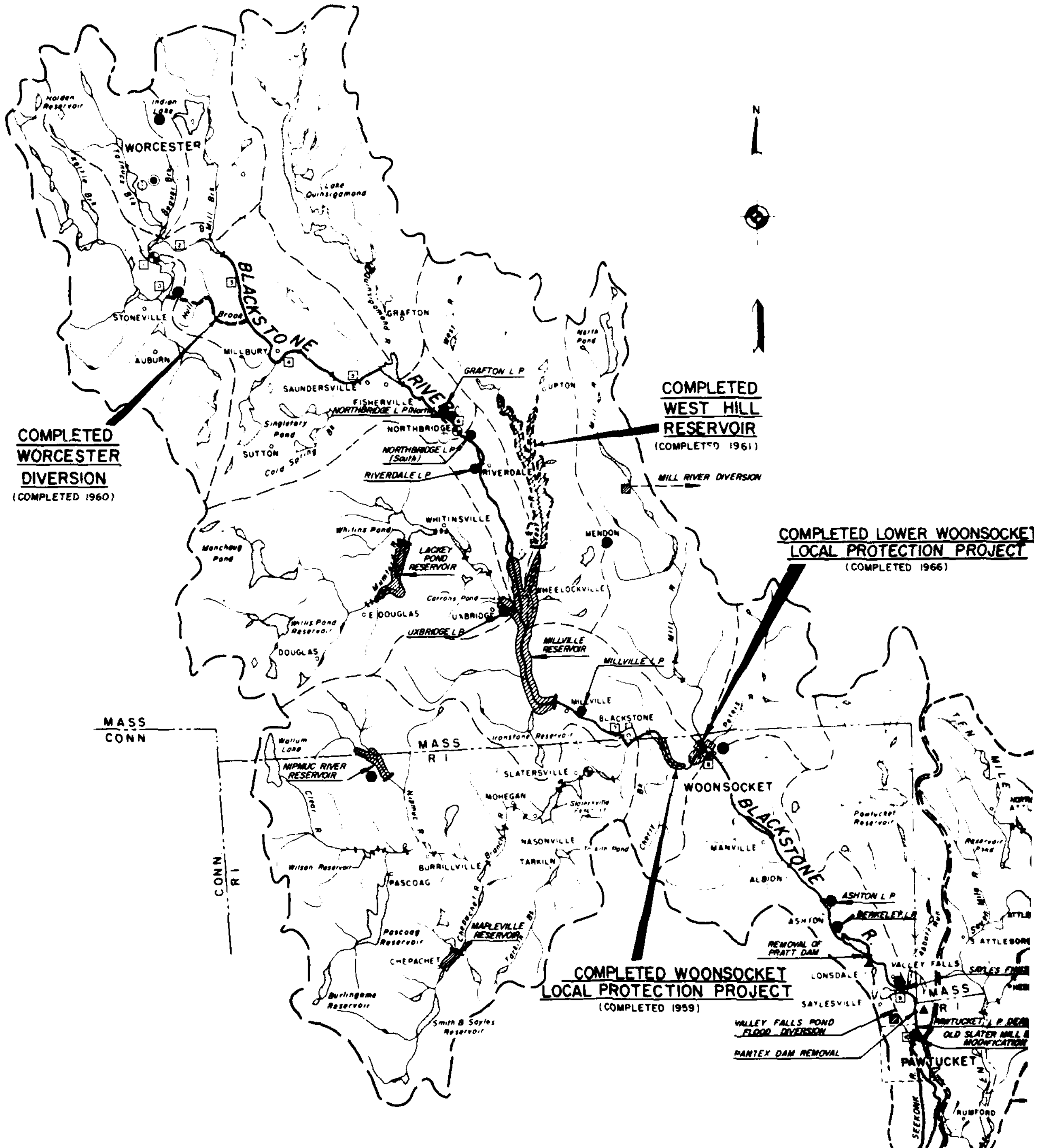
Studies of other reservoir sites (see Table 2-5) considered along the main stem in close proximity to the damage centers indicated that such sites would not provide sufficient floodwater storage. In addition to being socially and environmentally unacceptable, all sites were found to be economically prohibitive due to land acquisition and relocation costs

Understandably, the construction of any new reservoir is unpopular with the public as it inconveniences the people, temporarily upsets the community and affects the sociological, economic and ecological aspects of the area. However, the effectiveness of the evaluated reservoirs in reducing widespread flooding and alleviating damages to communities, as well as their ability to satisfy multiple objectives would result in greater utilization of the available natural resources within the study area.

Walls and Dikes - Concrete walls and earth dikes generally referred to as local protection projects were deemed to be an effective means for providing flood protection to high risk flood prone areas and, as a result, were considered for various communities in the Blackstone River Basin. Local protection studies initially were based on a design flood equal to the recurring 1955 storm. Of nine sites studied, it was found that potential economically feasible plans for the development of local protection works may be possible for Berkeley (Cumberland, Rhode Island) and Uxbridge, Massachusetts) and that Ashton (Cumberland, Rhode Island) should be considered in future studies.

Reservoir Management Program - The basic element in a reservoir management program is provision of floodwater storage by lowering the stages in existing reservoirs, thereby reducing peak flood discharges and potential damages. Within the study area many old mill dams, which were once the backbone of the manufacturing concerns that built them, have suffered from faulty operating problems and lack of periodic maintenance. Some dams have been abandoned or demolished and some impoundments have been converted to limited recreational usage.

The possibility of utilizing some of these dams by controlling their storage for flood control purposes was investigated. Our investigation revealed that they were not suitable for flood control. Most of the dams, particularly the smaller ones controlling rather small drainage areas, have been badly silted, reducing their limited effective storage. Without major modification, their value as flood control measures would be primarily in retarding the spring freshet and minor floodflows. The successful operation and maintenance of these dams to bring about any changes in flow conditions would require purchase of the riparian rights and operation by trained personnel. Proper operation cannot be assured by present dam owners.


COMPLETED WORCESTER DIVERSION
(COMPLETED 1960)
COMPLETED WEST HILL RESERVOIR
(COMPLETED 1961)
COMPLETED LOWER WOONSOCKET LOCAL PROTECTION PROJECT
(COMPLETED 1966)
COMPLETED WOONSOCKET LOCAL PROTECTION PROJECT
(COMPLETED 1959)
WORCESTER
BLACKSTONE RIVER
GRAFTON
GRAFTON L P
NORTHBRIDGE
RIVERDALE L P
MILL RIVER DIVERSION
WHITINSVILLE
LACKEY POND RESERVOIR
MENDON
UXBRIDGE
UXBRIDGE L P
MILLVILLE RESERVOIR
MILLVILLE L P
BLACKSTONE
NIPMUC RIVER RESERVOIR
MAPLEVILLE RESERVOIR
WOONSOCKET
ASHTON L P
REMOVAL OF PRATT DAM
VALLEY FALLS POND FLOOD DIVERSION
PANTEX DAM REMOVAL
PAWTUCKET
MASS
CONN
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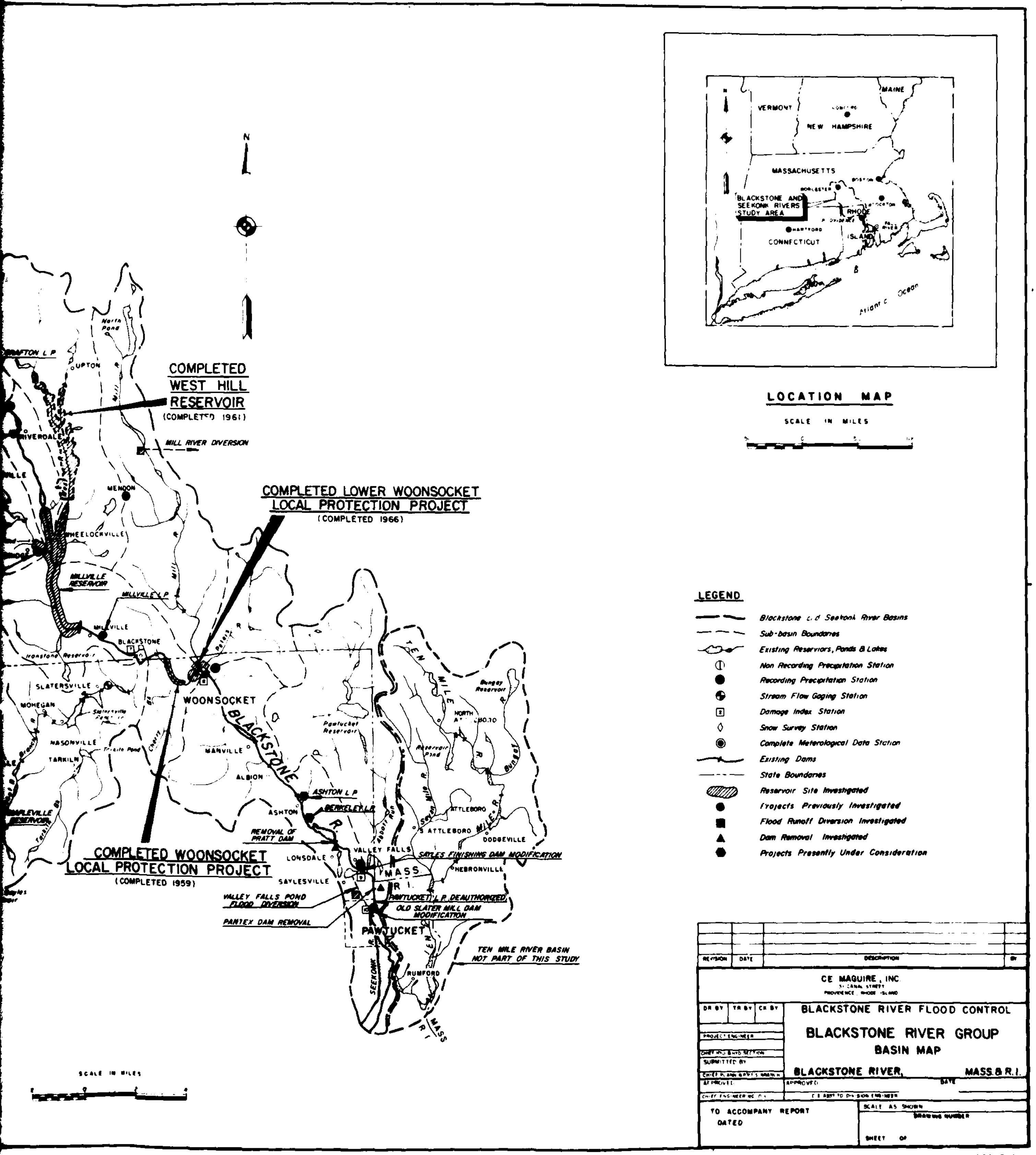
SCALE IN MILES


COMPLETED WEST HILL RESERVOIR
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(COMPLETED 1966)
COMPLETED WOONSOCKET LOCAL PROTECTION PROJECT
(COMPLETED 1959)
GRAFTON L P
UPTON
North Pond
RIVERDALE
MENDON
WHEELOCKVILLE
MILLVILLE RESERVOIR
MILLVILLE L P
MILLVILLE
BLACKSTONE
Ironstone Reservoir
SLATERSVILLE
MOHEGAN
MASONVILLE
TARKILN
WOONSOCKET
BLACKSTONE
MANVILLE
ALBION
Pawtucket Reservoir
ASHTON L P
BERKELEY L P
ASHTON
REMOVAL OF PRATT DAM
LONSDALE
VALLEY FALLS
SAYLES FINISHING DAM MODIFICATION
SAYLESVILLE
MASS
R I
VALLEY FALLS POND FLOOD DIVERSION
PAWTUCKET L P DEAUTHORIZED
OLD SLATER MILL DAM MODIFICATION
PANTEX DAM REMOVAL
PAWTUCKET
TEN MILE RIVER BASIN NOT PART OF THIS STUDY
SEEKONK R
RUMFORD
NORTH ATTLEBORO
ATTLEBORO
S ATTLEBORO
DODGEVILLE
HEBRONVILLE
TEN MILE R
Bungay Reservoir
SCALE IN MILES
VERMONT
NEW HAMPSHIRE
MAINE
MASSACHUSETTS
BLACKSTONE AND SEEKONK RIVERS STUDY AREA
RHODE ISLAND
CONNECTICUT
Atlantic Ocean
LOCATION MAP
SCALE IN MILES
LEGEND
Blackstone and Seekonk River Basins
Sub-basin Boundaries
Existing Reservoirs, Ponds & Lakes
Non Recording Precipitation Station
Recording Precipitation Station
Stream Flow Gaging Station
Damage Index Station
Snow Survey Station
Complete Meterological Data Station
Existing Dams
State Boundaries
Reservoir Site Investigated
Projects Previously Investigated
Flood Runoff Diversion Investigated
Dam Removal Investigated
Projects Presently Under Consideration
REVISION
DATE
DESCRIPTION
BY
CE MAGUIRE, INC.
PROVIDENCE, RHODE ISLAND
BLACKSTONE RIVER FLOOD CONTROL
BLACKSTONE RIVER GROUP
BASIN MAP
BLACKSTONE RIVER, MASS. & R.I.
PROJECT ENGINEER
SUBMITTED BY
APPROVED
DATE
TO ACCOMPANY REPORT
DATED
SCALE AS SHOWN
DRAWING NUMBER
SHEET OF

PLATE D 1

2

TABLE 2-5

PERTINENT DATA

OTHER FLOOD CONTROL RESERVOIRS STUDIED

RESERVOIR	LOCATION	PURPOSE	DRAINAGE AREA SQUARE MILES	STREAM	CAPACITY Run-Off Inches	CAPACITY Storage AC-Ft.	SPILLWAY CREST ELEV. MSL	PROJECT COST
Millville	Millville Mass	Flood Control	239	Blackstone River	2"	25,500	236	Too High by Insp
Fisherville	Grafton, Mass	Flood Control	154	Blackstone River	6"	42,840	335	Too High by Insp.
Grafton	" "	" "	36.9	Quinsigamond River	6"	11,800	323	13,020,000
Emerson Brook	Uxbridge, Mass	" "	5.3	Emerson Brook	11"	3,124	404	1,311,000
Pondville	Worcester, Mass	" "	5.05	Ramshorn Brook	10.6"	2,852	542	703,800
Brandy Brook	Glocester, R.I.	" "	5.09	Brandy Brook	8"	2,168	484	839,500
Keech Pond	Chepachet, R.I.	" "	5.95	Keech Pond	13"	4,121	450	823,400
Carpenter Reservoir	Northbridge Mass.	" "	5.57	Cpt. Rsvr.	8.4"	2,495	368	1,136,200
Round Top Brook	Douglas, Mass.	" "	8.96	Round Top Brook	14"	6,692	440	2,120,600
Clear River	Burrillville, R.I.	" "	8.09	Clear River	25"	10,775	495	3,088,900
Old Common Rsvr.	Blackstone, Mass.	" "	4.23	Ramshorn Brook	8"	1,800	571	471,600
W. Millbury Rsvr.	" "	" "	3.16	" "	8"	1,345	624	636,660
Cedar Swamp Rsvr.	" "	" "	2.08	Dark Brook	10"	1,110	603	227,940
Pond "626"	" "	" "	2.62	Pond "626"	8"	1,120	642	424,400
Purgatory Brook	Sutton, Mass.	" "	3.06	Purgatory Brook	8"	1,300	390	924,900
Aldrich Brook	Blackstone, Mass.	" "	3.15	Aldrich Brook	8"	1,344	292	602,500
Tarkiln Brook	Burrillville, R.I.	" "	3.80	Tarkiln Brook	12"	2,436	400	827,500
Lazy Hill Reservoir	Saundersville Mass.	" "	2.78	Unknown	8"	1,184	324	450,600
Chocalog Res.	Burrillville, R.I.	" "	3.72	Chocalog River	11"	2,178	442	612,500
Douglas State Forest	Douglas, Mass.	" "	2.59	Unknown	8"	1,104	690	848,900
Upper Carpenter	Northbridge, Mass.	" "	4.32	Mumford Tributary	19.1"	4,393	393	736,200
Lower Stockwell	Sutton, Mass.	" "	1.74	Singletary Brook	12.9"	1,200	609	361,600

Hurricane Barriers - Under adverse storm conditions, flooding along the main stem of the Blackstone River is not influenced by tides. Tidal flooding begins immediately downstream of the Main Street Dam, located just upstream of where the Blackstone River is not subject to tidal flooding. No further tidal flood protection analysis was required.

Stream Improvements - The channel conditions along the Blackstone River have been neglected to such a degree that such a storm of high frequency may affect the profile of the river. Some of the floods have been aggravated by either siltation, riverbank and lowland encroachment, inadequate bridge and culvert openings or general neglect in the removal of excessive vegetative growth and accumulated debris, particularly noticeable along the entire reach of the Blackstone River.

Means of remedying these conditions were evaluated within the realm of four major elements: adequate controls for rubbish disposal and general cleanup, channel modifications, removal of dams and diversion of floodflows as covered in the following text.

a. Adequate Controls for Rubbish Disposal and General Cleanup - The banks of the Blackstone River have long been used for open dumping. Recent environmental concern has renewed communities interest in general riverbank cleanup. Both Massachusetts and Rhode Island have enacted legislation designed to protect and preserve wetland areas (i.e., riverbanks). The State of Rhode Island Freshwater Wetlands Act of 1971 established a permit program to monitor all operations which would alter existing wetland areas. A similar program was established by Chapter 131-Section 40 of the Massachusetts General Laws as amended by Chapter 784 of the Acts of 1972. However, local ordinances, active campaigns and enforcement are desperately needed to clean and maintain the Blackstone River.

b. Channel Modification - Two local protection projects in Woonsocket, completed in 1960 and 1963 and consisting of extensive channel improvement work, dikes and floodwalls, have eliminated flood damage in most of the Woonsocket area. With completion of the Worcester Diversion Flood Control Project in 1960 extensive areas in Worcester were also afforded flood protection.

The Blackstone River flows from Worcester to Pawtucket through the sites of 24 existing or former industrial dams. Where these dams no longer exist, the former pond areas are either exposed or the river has assumed a channel or channels through the accumulated sediments behind the former dams. In its present course, the river has formed shallow or parallel channels so that any increase in flow causes an immediate overflow of low banks, and any unusual rise of water results in a wide spread of very shallow water. This study focused particularly on bends in the river subject to overbank flooding, restrictive bottlenecks or populated lowlands which become inundated.

Because of its history of high flood damage, one area considered for channel modification in this study was that reach of the Blackstone that extends from Ashton Dam to Pratt Dam in Cumberland-Lincoln, Rhode Island. As an alternative to the local protection projects at Ashton Dam and Berkeley, an analysis was made of widening and deepening the channels in conjunction with the removal of Pratt Dam and a railroad bridge.

It was found that floodwater surfaces could be lowered slightly but local protection would still be required at the two industrial areas of Ashton and Berkeley, Cumberland. A new highway bridge at Berkeley would be needed, and without further downstream modifications (dam removals) flood levels would increase at Valley Falls Pond, resulting in greater damages. This channel modification was, therefore, not considered further.

c. Removal of Dams - Several dams along the main stem of the Blackstone River were analyzed as alternative solutions to local protection to determine whether their removal would cause significant impact on flood stages and damage losses.

Replacement of the Old Slater Mill Dam - This could serve as an alternative solution to the Pawtucket local protection project, previously authorized in 1944 and deauthorized in 1977. Because of its historical significance (Old Slater Mill was the first successful cotton spinning mill in the United States), the Pawtucket Redevelopment Agency and the Preservation Society have requested that the pool behind the existing dam be maintained for aesthetic reasons.

Removal of Pantex Dam - The removal of Pantex Dam in Pawtucket, Rhode Island, at river station 44+00 does not appear to be justified as a separate element. Its removal would lower the recurring 1955 flood stage only a negligible amount, generating little benefit to offset initial first costs. It was therefore not considered further.

Removal of Sayles Finishing Dam - Removal of the Sayles Finishing Dam in Central Falls, Rhode Island at river station 10+00 would reduce the flood stage an average of 3.0 feet from the dam site upstream to the Martin Street Bridge in Cumberland. The dam removal would also increase velocities from an average of 6.0 to 12.0 feet per second at the Broad Street Bridge. Above Valley Falls Pond the velocities would increase about one foot per second up to Martin Street with no change in velocities occurring upstream of this reach.

Initial construction costs for removal of the dam include stone slope protection from the Broad Street Bridge upstream to Valley Falls Pond and at Mendon Road highway bridge. The estimate also includes an amount for removal of silt accumulated behind the dam.

However, removal of this dam would effectively drain Valley Falls Pond, an area already acquired for conservation and recreation by the State of Rhode Island. Problems relating to the protection of the drained pond area, the use of the present pond area as a source of sprinkler fire protection and the cost associated with the removal and disposal of extensive silt deposits are other items which required further study.

Removal of Pratt Dam - Also included in this study was the removal of the currently ungated Pratt Dam in Cumberland-Lincoln, Rhode Island. At present, the riverflow has been diverted through the gate structure of the dam by localizing landfilling operations, leaving the dam ineffective except in periods of extreme flooding. With the approach channel to the dam reopened and the dam removed, the recurring 1955 flood stage would be reduced an average of less than one foot for the reach of the river from the dam site to Martin Street upstream. An examination of the damage data for this area indicates that major damage occurs farther upstream and that benefits accrued to this improvement would be insignificant.

d. Diversion of Floodwaters -

Mill River - The potential for diverting storm runoff from the Upper Mill River watershed at Hopedale to the Upper Charles River Basin was investigated. The diversion would reduce flood stages along the Mill River and the Blackstone River and could provide low flow augmentation possibilities for the Upper Charles River. The entire basin drainage area of 20 square miles is almost totally located within Massachusetts. Its shape is decidedly elongated, being 10 miles along with an average width slightly in excess of two miles. The largest impoundment within the basin is Harris Pond Dam in the town of Blackstone, Massachusetts. The Harris Pond Dam failed and multiplied problems for the city of Woonsocket during the 1955 record flood.

Although the basin's shape and close proximity to the Upper Charles River appears to lend itself to diversion, it was found that diverting part of the basin's runoff did not reduce flood stage significantly and that cost exceeded the benefits derived for low flow augmentation. In addition, the city of Woonsocket at present uses Harris Pond as an emergency water supply for their system as well as low flow facility for World War II Memorial Park, and demands on city supplies are increasing rapidly. For these reasons, this diversion was not considered further.

Valley Falls Pond - As an alternative to local protection or dam removal a diversion tunnel was considered for the Central Falls-Pawtucket area. A tunnel with gates and inlet structure located at Valley Falls Pond could divert flows directly to the Division Street area and Pawtucket, thereby bypassing a high damage area. Benefits were not sufficient to justify the cost of such a project so the diversion was eliminated from consideration.

Floodproofing - Floodproofing was considered as an alternative measure in this study for structures in the flood plain that experienced damage from floodflows a few feet deep.

Urban Redevelopment - Urban redevelopment presents an excellent opportunity for communities to remove developments from flood plains and place them in secure areas and to make sure that new construction in flood plains is designed to withstand flooding.

A community planning urban redevelopment should first submit a request for a flood plain information study to their State Department of Natural Resources or other designated State agency. Zoning ordinances based on the study report should then be enacted.

Conclusion - The results, after consideration of many possible solutions, show that only a limited number of measures met the minimum acceptable plan requirements.

The process of considering these alternatives further revealed that there are eight projects worthy of more detailed analysis. The results of this analysis are presented in the following text.

ALTERNATIVES CONSIDERED FURTHER

The ensuring step in the plan selection and formulation process entailed refinement of individual measures that passed the preliminary screening test. The next step continued with a more detailed identification of the measures that could provide an adequate degree of protection to major damage areas.

Mapleville Reservoir - The project would be located in northwestern Rhode Island within the towns of Burrillville and Glocester. The dam would be situated across the Chepachet River upstream of the upper extremities of Gilleran Pond, or about 1/4-mile south of the village of Mapleville. At full flood control pool elevation, 390 feet NGVD, the reservoir would extend to the village of Chepachet at U.S. Route 44. As currently considered, the project would be a multipurpose facility providing, in addition to flood control, an entirely new water-oriented recreational development to the area (see Figure 2-2).

With the implementation of the State Water Quality Standards and PL 92-500, the Federal Water Pollution Control Act as amended, this stretch of the Chepachet River, currently a Class C stream, should be upgraded to Class B. Thus, the recreation storage could be used as a means of satisfying a portion of the water supply demand. This would then mandate that the recreation usage would be limited to noncontact aspects. It is estimated that a dependable yield of 12 million gallons a day (MGD) could be realized from such a conversion. This would, however, necessitate certain land use restrictions and some form of water treatment system for the proposed reservoir.

It is unlikely, however, that this project could be called upon to meet immediate demands since the water quality of the Nipmuc project is far superior to that of the Chepachet River. It is primarily for this reason that recreation was added as a project purpose. Should it be demonstrated that the water supply potential of this site has a higher priority than recreation and that the water quality of the Chepachet River is more acceptable than the Nipmuc River, then further evaluation of the water supply needs could be required.

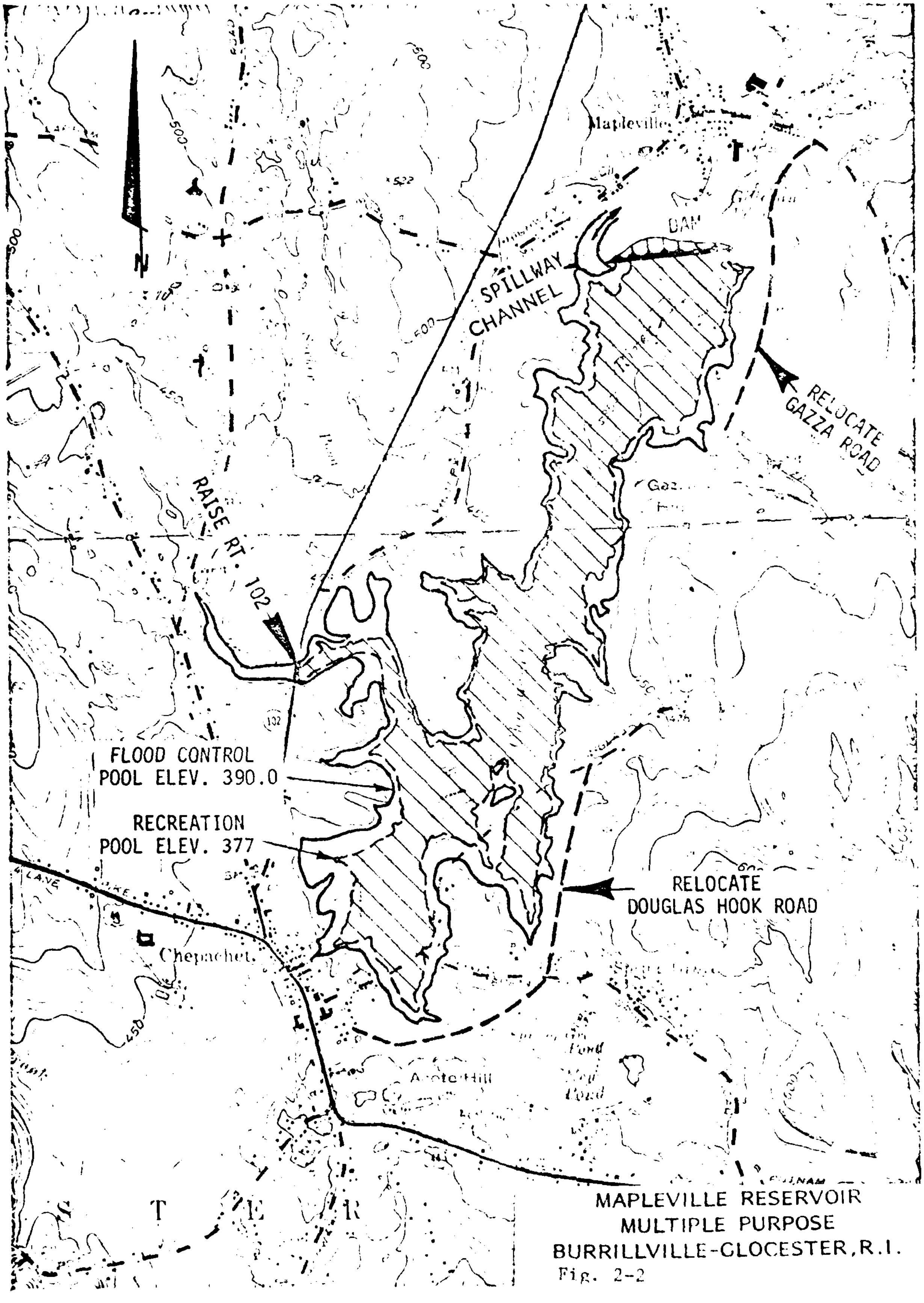
The Mapleville Reservoir dam would have a top elevation of 402 feet NGVD and would consist of a rolled earthfill structure 70 feet high and 1,900 feet in length with a concrete chute spillway located on the west abutment. At spillway crest elevation 390, the reservoir would be capable of impounding a total storage of 12,700 acre-feet of which 6,460 acre-feet, equivalent to a surface area of less than 410 acres, would be used for recreation activities. The remaining storage of 6,240 acre-feet would be reserved to control an equivalent of 6 inches of runoff from an intercepted drainage area of 19.5 square miles.

The reservoir area would be in an open and gentle sloping valley, covered by moderate growth and scattered small shallow ponds at the upper end of the reservoir periphery. The impoundment area is rural and sparsely populated; but urbanization has increased moderately along the upper extremities in Chepachet, a small village located along the four lane Putnam Pike (U.S. Route 44). At the dam site, the terrain is somewhat narrow and steepsided with an overburden consisting mainly of sand and gravel and no evidence of bedrock.

Minor modification and 2.3 miles of relocation would be required of three local roads. Route 102 on the westerly side would be raised a maximum height of approximately 14 feet for a distance of 1,000 feet, including reconstruction of a bridge crossing Sucker Brook. Two secondary roads, Gazza and Douglas Hook, would be relocated 1.0 and 1.3 miles, respectively. In addition, one small cemetery within the reservoir area would require relocation; another within the buffer zone would be waived.

Total real estate acquisition would include the outright purchase of about 570 acres for the dam, work areas and the reservoir area up to spillway crest elevation 390. An additional 170 acres would be needed for a 300-foot horizontal buffer zone along the periphery of the reservoir above spillway crest. A total of 40 buildings would have to be purchased or relocated, 32 from within the buffer zone.

The economic benefit/cost ratio based on flood control separable costs at 6-3/8 percent (FY 77) is 0.67. Consequently the project, according to the Corps of Engineers criteria, is not economically feasible, does not produce any environmental benefits and will not be considered further.



MAPLEVILLE RESERVOIR
MULTIPLE PURPOSE
BURRILLVILLE-GLOCESTER, R.I.
Fig. 2-2

Lackey Reservoir - The reservoir would be located on the Mumford River entirely in Massachusetts within the towns of Douglas, Uxbridge, Sutton and Northbridge. The dam site, straddling the Sutton-Northbridge town line within the confines of Whitins Pond along the Mumford River, would be located approximately 1,000 feet downstream from Lackey Pond Dam, approximately five miles west of the village of Whitinsville. As considered, the project would be multipurpose with flood control and water oriented recreation activities (see Figure 2-3).

The dam would be a rolled earthfill structure approximately 64 feet high and 1,900 feet long with a top width of 30 feet. The spillway crest would be at elevation 349 feet NGVD with a 10-foot surcharge and 5-foot freeboard allowance setting the top of the dam at elevation 364. The spillway, a concrete chute type, would be located on the northwest abutment of the dam. At spillway crest elevation 349 NGVD, the optimum capacity of the reservoir would be 16,500 acre-feet, equivalent to a surface area of 670 acres. Of this amount, 10,650 acre-feet equivalent to 6 inches of runoff from a watershed of 33.3 square miles, would be allocated for flood control. The recreational pool at elevation 330 would contain 5,850 acre-feet of storage and provide 430 acres of water oriented recreational activities.

The land in the proposed reservoir area is rural in character and contains homesites, tillable and pastureland, woodland and developable land.

Preliminary geological surveys indicate the dam site is entirely wooded but readily accessible. The right abutment appears to consist of very bouldery, sandy glacial till but may be comprised of some sand and gravel. The left abutment is composed of bouldery sand and gravel. No bedrock exposures were noted in the immediate vicinity of the spillway area.

Land acquisition, including the 300-foot buffer zone, would encompass an area of 935 acres, of which 150 acres would be acquired by riparian rights. Approximately 60 dwellings and two manufacturing complexes would be affected.

Relocation would include about 0.5 miles of Douglas Road in Douglas and Hartford Street, North Street and Gelboa Street. Route 146 would be raised and its embankment slopes protected by riprap armoring. The cloverleaf intersection at Lackey Dam Road and Route 146 would be abandoned at its present location and a new interchange provided west of the reservoir. Access to the new interchange from the East Douglas area to the south and the Prentice Corner area on the north would require the construction of a new roadway paralleling the western shore of the reservoir.

Present estimates for the raising and protection of Route 146 through the reservoir are based on its present size. However, studies have been conducted by the Massachusetts Department of Public Works to increase the roadway's capacity by widening it to four lanes.

Electric power transmission lines that pass through the middle of this project would need to be raised, and the gravel packed well that supplies water to the village of Whitinsville would be adversely affected.

The economic benefit/cost ratio based on flood control separable costs at 6-3/8 percent (FY 77) is 0.48. Therefore, the project, according to the Corps of Engineers criteria, is not economicaly feasible, does not produce any environmental benefits and will not be considered further.

Nipmuc River Dam and Reservoir

a. Social and Economic Considerations - The project is located in the town of Burrillville, Rhode Island, and extends upstream across the Rhode Island-Massachusetts State line into the town of Douglas, Massachusett. As contemplated, the reservoir would provide only a limited degree of flood protection to existing development along the main stem of the Blackstone; it would provide a somewhat greater degree of protection to existing development along the Branch River (and the Pascoag and Nipmuc Rivers) and the Mumford River. The construction of the reservoir would reduce the average annual flood damages in Pawtucket, Central Falls, Cumberland, and Lincoln by $247,500 as detailed in Appendix 7, Economics. It would also reduce damages by approximately $72,000, or 50 percent, for the two towns located on the Branch River (North Smithfield and Burrillville). See Plate D-2.

As considered, the Nipmuc Reservoir would be a multipurpose reservoir providing both flood control and water supply. The reservoir would flood a sparsely settled, wooded area which is planned for continued settlement at rural densities or for possible development as a water supply source and conservation area.*

The topography of the project site is rock controlled with a mantle of deposits covering most of the area. The immediate neighborhood of the area, however, consists of a mixture of vacant land, older single family dwellings, and recently constructed single family dwellings.

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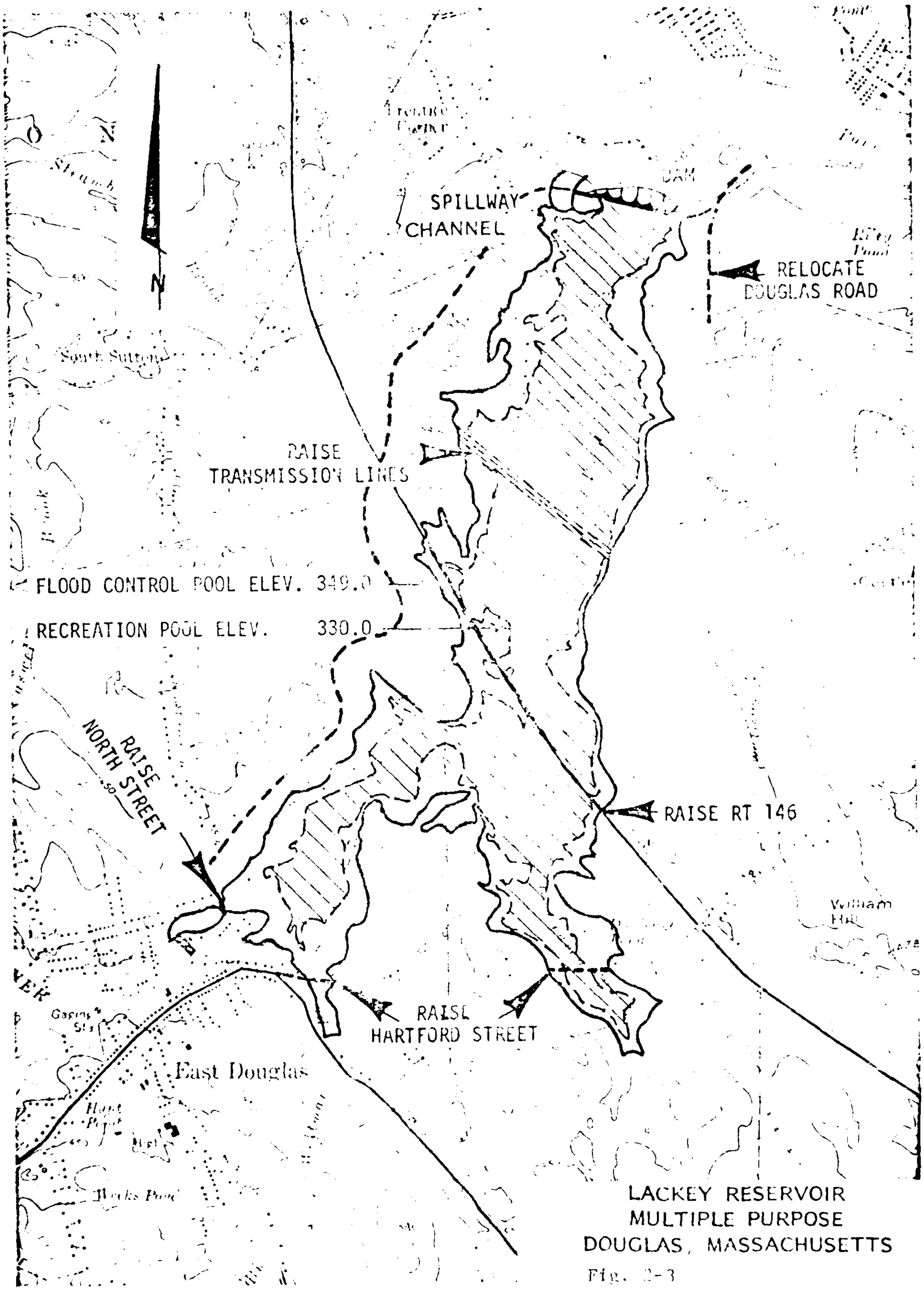
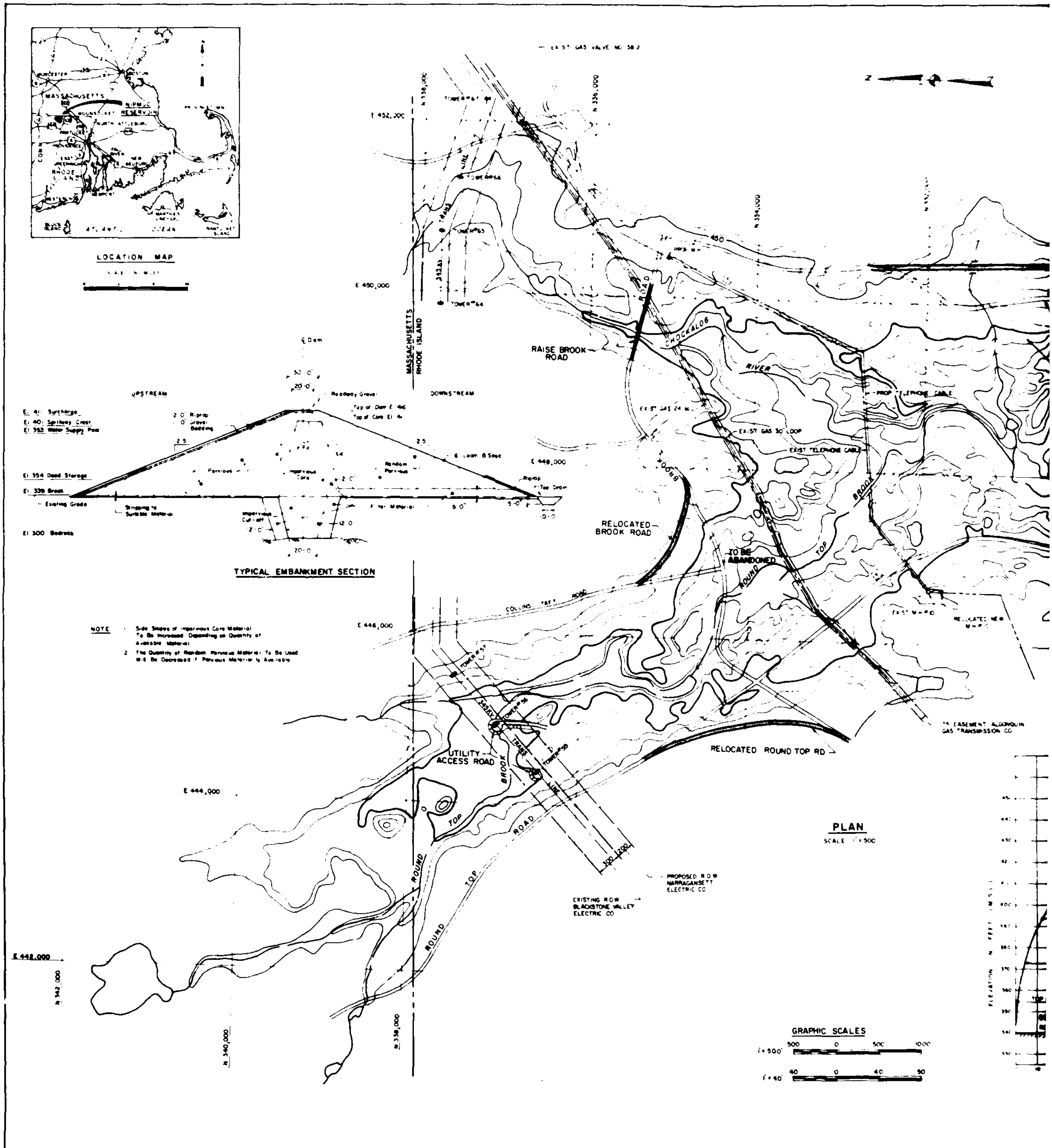
*The Comprehensive Community Plan of the town of Burrillville, Rhode Island suggests rural densities, while the State Land Use Policies and Plan of the State of Rhode Island proposes water supply and conservation.



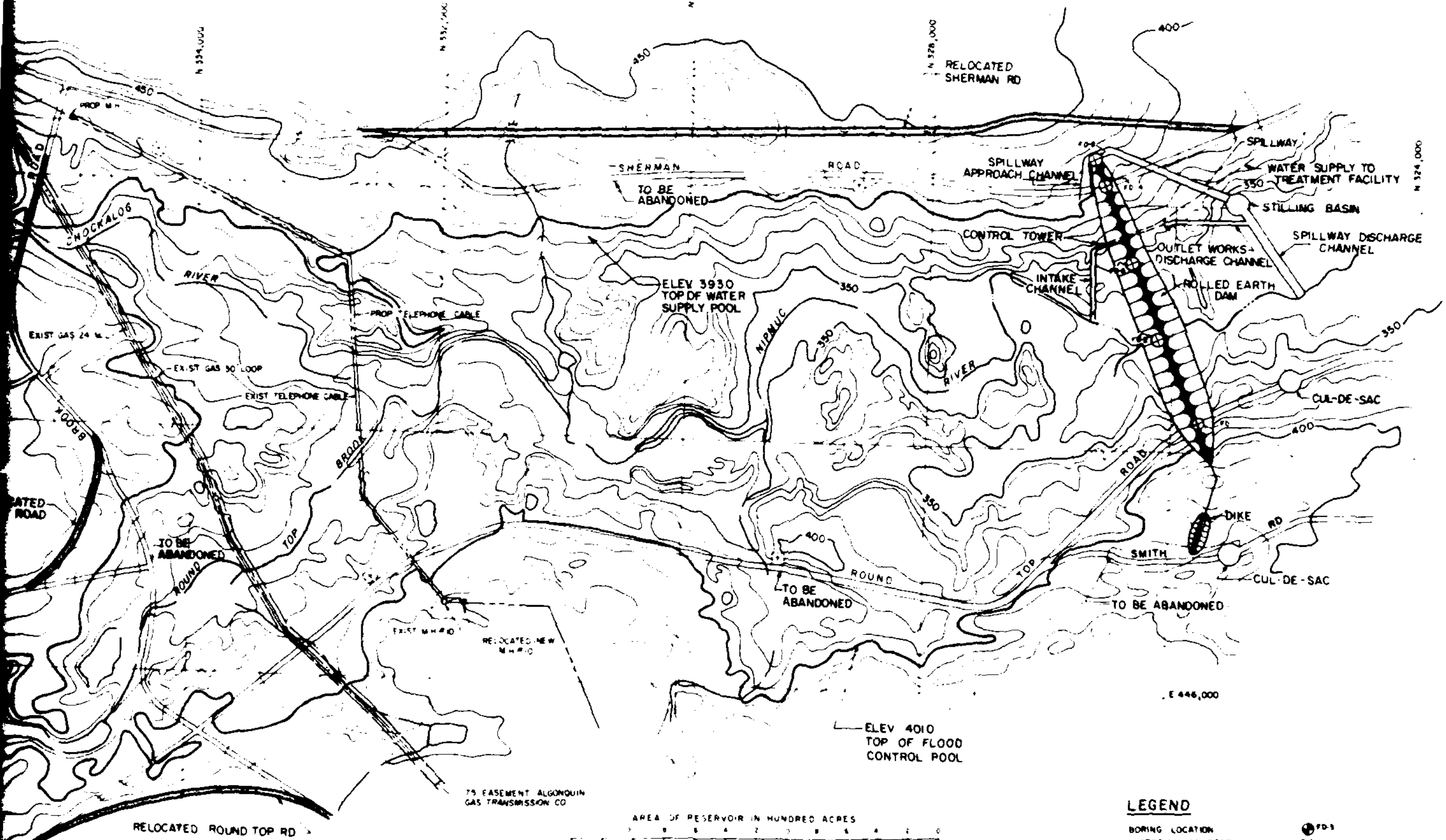
LACKEY RESERVOIR
MULTIPLE PURPOSE
DOUGLAS, MASSACHUSETTS

Fig. 2-3


LOCATION MAP
MASSACHUSETTS
RHODE ISLAND
NIPMUC RESERVOIR
ATLANTIC OCEAN
TYPICAL EMBANKMENT SECTION
UPSTREAM
DOWNSTREAM
El 41 Surcharge
El 40 Spillway Crest
El 393 Water Supply Pool
El 354 Dead Storage
El 339 Brook
El 300 Bedrock
Existing Grade
Stripping to Suitable Material
Impervious Cut-off
Pervious
Impervious Core
Random Pervious
Filter Material
Riprap
Toe Drain
Roadway Gravel
Top of Dam El 416
Top of Core El 41
6 Loam & Seed
2.0 Riprap
1.0 Gravel Bedding
30.0
20.0
20.0
12.0
8.0
5.0
NOTE
1. Side Slopes of Impervious Core Material To Be Increased Depending on Quantity of Available Material
2. The Quantity of Random Pervious Material To Be Used Will Be Decreased If Pervious Material Is Available
MASSACHUSETTS
RHODE ISLAND
E 452,000
E 450,000
E 448,000
E 446,000
E 444,000
E 442,000
N 336,000
N 338,000
N 340,000
N 342,000
N 354,000
EXIST GAS VALVE NO. 38.2
TOWER 67
TOWER 66
TOWER 65
TOWER 64
TOWER 57
TOWER 56
TOWER 55
345 KV TRANS LINE
RAISE BROOK ROAD
BROOK ROAD
CHOCKALOG RIVER
EXIST GAS 24
EXIST GAS 30 LOOP
EXIST TELEPHONE CABLE
PROP TELEPHONE CABLE
RELOCATED BROOK ROAD
TO BE ABANDONED
ROUND TOP BROOK
ROUND TOP ROAD
COLLINS TAFT ROAD
UTILITY ACCESS ROAD
RELOCATED ROUND TOP RD
EASEMENT ALGONQUIN GAS TRANSMISSION CO
PROPOSED ROW NARRAGANSETT ELECTRIC CO
EXISTING ROW BLACKSTONE VALLEY ELECTRIC CO
PLAN
SCALE 1" = 500'
GRAPHIC SCALES
1" = 500'
500 0 500 1000
1" = 40'
40 0 40 80
ELEVATION IN FEET M.S.L.

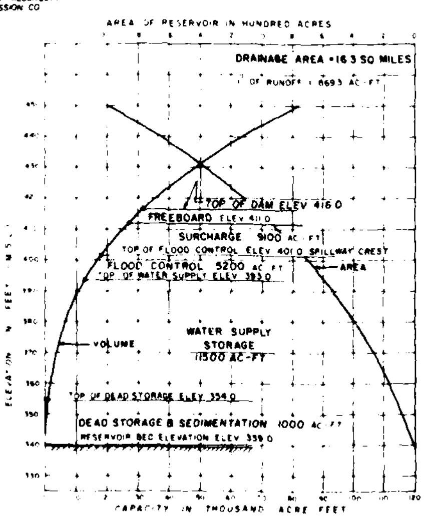
1

H



PLAN

GRAPHIC SCALES



AREA-CAPACITY CURVES

CE MAGUIRE ARCHITECTS ENGINEERS PLANNERS	DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS

DES BY SK | DR BY ED | CK BY AR

WATER RESOURCES STUDY

NIPMUC RESERVOIR

GENERAL PLAN

NIPMUC RIVER — BURRILLVILLE, RHODE ISLAND

SCALE AS SHOWN

SHEET 1 OF 1

PLATE D 2

The Reservoir would take approximately 1,200 acres, with close to 95 percent situated in Burrillville with the remaining 5 percent in Douglas. As mentioned before, the area to be flooded has been settled at low or "rural" densities. Land takings, however, would include 110 acres of developed residential homesites including close to 40 residential structures. Vacant potentially developable land (614 acres), wetlands (250 acres), wooded land (250 acres), two recreational areas, and four cemeteries would be inundated by the reservoir. The two recreational properties are located on Brook Road and include the Wallum Lake Rod and Gun Club, and the Round Top Fishing Area. Relocations of the cemeteries would be accomplished as part of the project.

In addition to relocated residences, the inundation by the reservoir would require the relocation of 1.7 miles of Round Top Road, and 0.45 miles of Collins Taft Road. Brook Road would be raised for a length of 0.21 miles. Although these relocations may require alternate routes which are more circuitous than those routes they replace, traffic volume in this area is estimated to be quite low, so no significant traffic flow or related problems would be expected.

The construction of the Nipmuc Reservoir and dam would temporarily degrade air quality, noise, traffic, and safety conditions in areas adjacent to construction and along truck access routes. These impacts can be reduced by specified sequences of acquisition and construction. Relocation of residents prior to the start of construction would reduce construction related impacts. Also, initial relocations of Round Top and Sherman Roads would provide bypass route permitting the separation of community traffic from construction traffic.

Construction of the dam would require quantities of materials, such as gravel, rock, and concrete. Although the source of these materials is not known it is likely that truck access would be from the roadway network to the south, due to the presence of numerous sand, gravel, and stone pits to the south of the dam site. The various possible access routes pass through residential zones and built-up areas such as Graniteville and Harrisville. These areas would be subject to the range of impacts associated with heavy truck traffic--degraded air quality, noise, traffic congestion, and safety hazards.

The project would consist of a rolled earth dam and dike at the southwest end of the dam, a chute type spillway in the southeast dam abutment and outlet works consisting of a control tower, service bridge and discharge outlet.

The construction period would take over two years and would require fewer workers during initial and phase-out periods than during peak periods of construction activities. Considerable impacts would be felt if large numbers of construction workers were to move nearer construction activities during the construction period. Potential effects on local services, local business establishments, and the housing market would be investigated.

b. Estimates of Cost

First Costs - Unit prices used in estimated construction and relocation costs are based on average bid prices for similar work in the general area, adjusted to the June 1976 price level. Valuations of real estate area based on recent assessments and include additional costs for resettlement and acquisition. All construction costs include an allowance of 20 percent for contingencies. The total cost of the project is estimated at $26,357,000. A summary of the cost of the various features of the work is given in Table 2-6.

Accrued interest during construction is computed on the basis of a three year construction period. This was derived by multiplying the total construction expenditures by the 6-3/8 percent interest rate, prevailing rate at that time, and by one-half of the three year construction period.

Annual Charges - A summary breakdown of annual charges is shown in the cost allocation Table 2-7.

The project was considered to have an economic life of 100-years. Interest was computed at 6-3/8 percent, prevailing rate at that time, amortized over a 100-year period.

Operation and Maintenance - This item is estimated on the basis of experience with similar projects in the New England area. Included are costs for maintenance of the project structures and for operation of the multipurpose project features. It also includes operational procedures for the flood control and water supply gates as well as the permanent operating equipment and gages for monitoring and recording the water supply and fluctuating storage in the reservoir.

Major Replacement - Allowance is made for replacement of dams deemed to have a usable life of less than the projected span of 100-years. Included in the replacement cost are types of equipment used in the operation of the project such as gates, heating and hydraulic systems, pumps and generators.

c. Cost Allocation

Allocation of Costs Among Purposes - Cost of the multiple purpose reservoir allotted to the purposes of flood control and water supply were made by the Separable Costs Remaining Benefits method. A detailed breakdown of allocation among project purposes is shown in Table 2-7.

TABLE 2-6

FIRST COSTS _ NIPMUC RESERVOIR

(June 1976 Price Level)

Lands and Damages		$ 4,842,000
Reservoir Clearing		344,400
Relocations	$ 279,700	
Utilities	2,001,000	
Cemeteries	260,000	
	2,540,700	
Contingencies (20%)	508,140	
	3,048,840	3,048,840
Dam and Appurtenant Structures		
a.Preparation of Site	1,472,700	
b.Embankment	7,458,700	
c.Concrete	2,450,250	
d.Outlet Works	233,000	
e.Miscellaneous	590,900	
	12,205,550	
Contingencies (20%)	2,441,110	
	14,646,660	14,646,660
Buildings, Grounds and Utilities		25,000
	Subtotal	$22,906,900
Engineering and Design (11%) of 18,064,940		1,987,140
Supervision and Administration		1,463,260
TOTAL FIRST COST		$26,357,300

TABLE 2-7

COST ALOCATION SUMMARY - NIMPUC RESERVOIR
(June 76 Price Level)

Purpose	First Cost	Annual Charges
Flood Control	$ 3,589,000	$ 302,000
Joint Use	12,779,000	--
Water Supply	9,989,000	745,000
Total	$26,357,000	$1,047,000

Comparison of Benefits and Costs - A comparison of benefits accruing to each project purpose with the costs allocated to the respective purposes indicates that flood control is not economically justified (see Table 2-8).

TABLE 2-8

ECONOMIC ANALYSIS - NIPMUC RESERVOIR

Purpose	Annual Benefits	Annual Costs	Benefit/Cost Ratio
Flood Control	$242,000	$312,000	0.80
Joint Use	--	--	--
Water Supply	775,000	775,000	1.0

Other costs and combined economic benefits were also developed* for this project and the final benefit/cost ratio at the 1976 price level was 0.8. The project does not produce any environmental or economic net benefits and therefore according to the Corps of Engineers criteria the project is unfavorable and will not be investigated further.

Modification of Old Slater Mill Dam

a. General - Two channel improvement alternatives were considered in Pawtucket, Rhode Island at the site of the historic Old Slater Mill. In the first the existing dam would be modified by lowering and replacing the present dam crest with bascule type gates. Due to the historical significance of the structure (Slater Mill was the first successful cotton spinning mill in the United States), the Pawtucket Redevelopment Agency and the Preservation Society requested that the pool behind the existing dam be maintained for aesthetic reasons. By replacing the existing dam with a bascule type gate structure, the pool would not only be preserved but the modification would also permit passage of floodflows equal in

*See Appendix 4

magnitude to the storm of record that occurred in August 1955, thus preventing backwater flooding of commercial and industrial properties. Stone slope protection would be replaced at locations immediately upstream from the dam to prevent erosion of building and bridge foundations. Upstream retaining walls would need to be increased in height and backed by a reinforced "L" type concrete floodwall to prevent overtopping from expected floodflows and buildings would have to be floodproofed (see Plate D-3). The second alternative consisted of channel slope protection, raising of the floodwalls and floodproofing the adjacent buildings but did not include the dam modification.

b. Social and Economic Considerations - The Slater Mill Dam Project would lower flood stages as far upstream as the Pantex Dam. The existing dam is not functioning p operly, and many of the commercial and industrial properties situated upstream of the dam have been subjected to recurring flood problems. Lowering of the flood stage along this reach of the river would prevent the inundation of sections of Roosevelt Avenue in Pawtucket during extreme floodflows. Estimates indicate that modifications to the dam would reduce annual losses in Pawtucket by $350,300.

Modification of the dam would reduce flood damages to the Slater Mill and to commercial and industrial properties immediately upstream of the dam site. In addition to about a dozen industrial complexes that receive flood damages upstream is the Pawtucket Municipal Building. Since the flood plain areas along this reach are already fully developed, no additional development can be anticipated.

Construction including the bascule gate structures and adjacent stone slopes, would generate some degree of dust, diesel exhaust, and noise from on site equipment and from trucks along the access route. The construction activities would create additional traffic in the downtown area of the Pawtucket, causing even greater congestion. Some buildings not protected by floodwalls would be floodproofed by bricking of window openings, installation of aluminum shielding for doors, fitting of backwater valves for riverside drainage, and application of a waterproofing agent to building walls and foundations within the flood stage limits. These activities would require approximately 35,000 square feet of interior building space as temporary easements and could interrupt regular activities within those areas. It is anticipated that the project would take approximately one year to complete. Most adverse effects to be experienced, however, would be short term.

c. Description of Structures

Bascule Gates - The gates considered for this modification would be "Pelican" style with the two leaves, 3'0" x 82'6", anchored to the lowered crest. The gate is basically a long leaf type structure hinged along its bottom edge and operated hydraulically. The operator is activated by a float sensor installed on the west abutment to measure upstream water levels. The leaves would be 3'0" high to maintain the original crest

elevation (El. 24.08 NGVD), but when activated would lower to a fully open position, providing a modified crest elevation of 21.08 to pass flood-flows. Fully open, the gate leaf rests on the dam crest and presents no obstacle to the flow. As floodwaters recede, the gates would automatically raise, restoring the upstream storages.

Channel Work - Channel improvement would, in general, consist of placing stone slope protection along existing foundation and retaining walls that abut the river's edge. A total of approximately 4,410 feet of protection would be provided on both streambanks upstream of Old Slater Mill. Stone would be placed on supporting bedding material at a slope of 1 on 2.

Walls - Existing retaining walls along the streambank would be reinforced and increased in height to prevent overtopping. In general, the construction would raise the existing stone masonry wall and reinforce it with a reinforced concrete "L" wall. A total of approximately 2,140 feet of wall would have to be raised and reinforced at various locations.

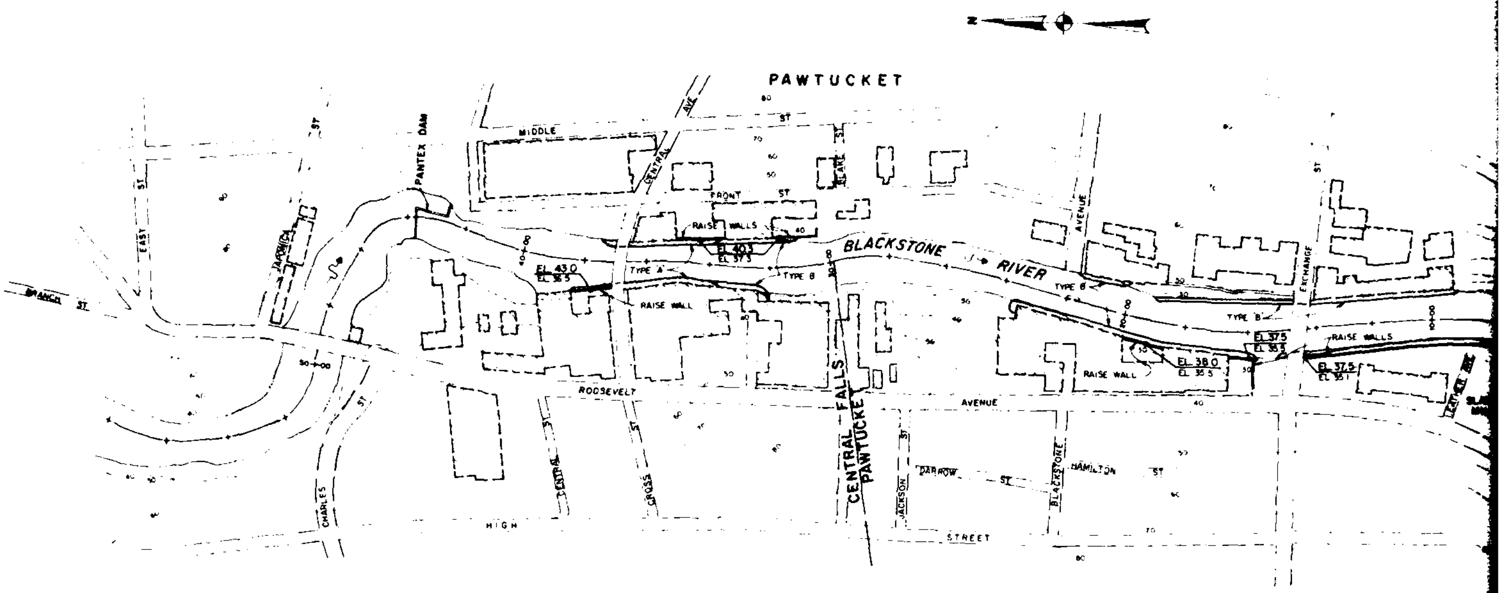
Floodproofing - In general, the floodproofing of buildings not protected by floodwalls would include bricking up window openings, installing aluminum shielding on doors, fitting backwater valves for riverside drainage and applying a waterproofing agent to building walls and foundations within the flood stage limits. Walls that cannot be floodproofed with reasonable assurance of strength against the water pressure would be replaced with reinforced concrete block walls and coated with a waterproofing agent.

d. Estimates of Costs

First Costs - A detailed breakdown of first costs for the modification plan is shown in Table 2-9. Table 2-10 shows first costs for the second alternative.

Annual Charges - The estimate of Federal annual charges is based on interest at 6-3/8 percent on the Federal investment plus the amount required to amortize the investment over the assumed 50-year life of the project. Non-Federal interest and amortization charges were computed in a similar manner at the same interest rate. Non-Federal charges also include amounts for maintenance and operation of the project and an interim replacement of equipment having an estimated life of less than 50-years. The derivation of annual charges is given in Table 2-11. Table 2-12 shows the derivation of annual charges for the second alternative.

e. Project Formulation - Annual benefits accruing to the projects in the area to be protected are estimated to be $269,000. Annual charge for the first alternate (with bascule gates) is estimated at $379,100, resulting in a economic benefit/cost ratio of 0.71 to 1. Annual cost for the second alternate is estimated at $320,610, resulting in an economic benefit/cost ratio of 0.84 to 1. Both alternatives are not economically justified and provide no environmental benefits and therefore they were not considered further.

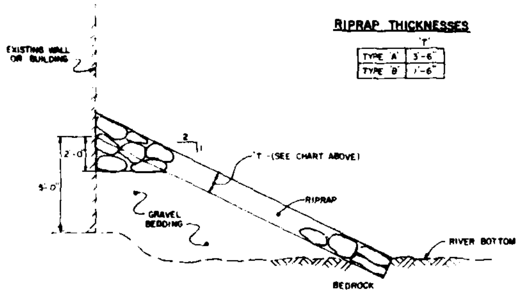


PLAN

SCALE 1"=200'

RIPRAP THICKNESSES

	'T'
TYPE A	3'-6"
TYPE B	1'-6"

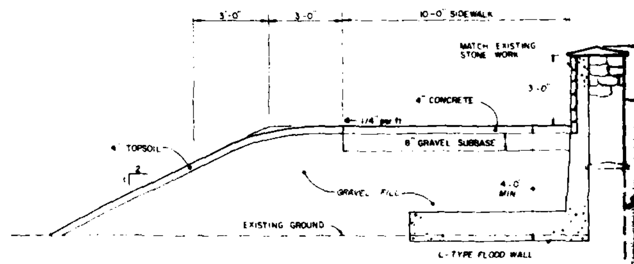


TYPICAL STONE PROTECTION

FOR

EXISTING WALLS AND BUILDING FOUNDATIONS

NOT TO SCALE

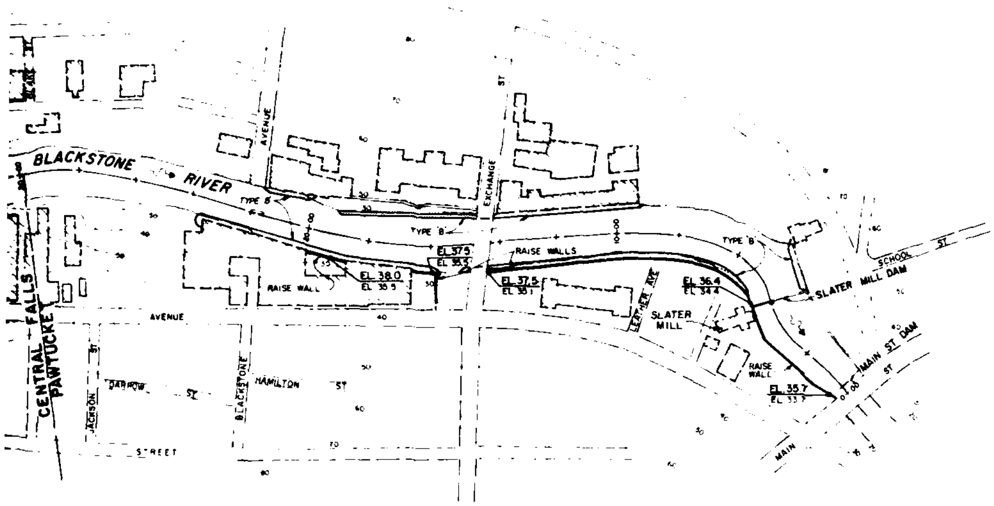


WALL MODIFICATION

WEST BANK - STA 0+00 TO 4+00

NOT TO SCALE

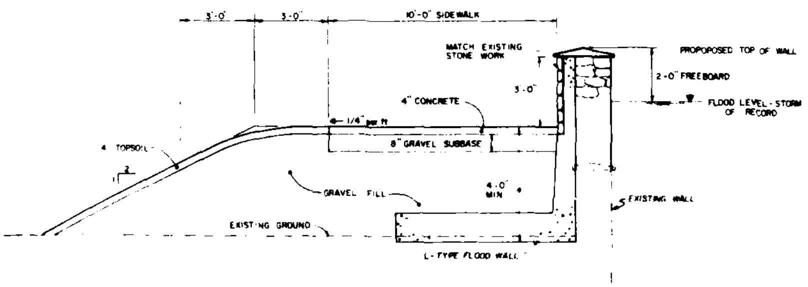
REVISION	DATE	DESCRIPTION	BY



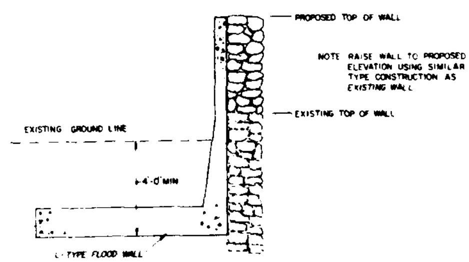
LEGEND

- TYPE 'A' STONE PROTECTION
- TYPE 'B' STONE PROTECTION
- EXISTING WALL TO BE RAISED
- EL 00 PROPOSED TOP OF WALL / EL 00 EXISTING TOP OF WALL
- BUILDING TO BE FLOOD PROOFED

PLAN
SCALE 1"=200'

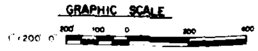


WALL MODIFICATION
WEST BANK - STA 0+00 TO 4+00
NOT TO SCALE



TYPICAL WALL MODIFICATION
NOT TO SCALE

GRAPHIC SCALE



CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS
PROVIDENCE, R.I. WALTHAM, MASS. NEW BRITAIN, CONN.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES BY	DR BY	CK BY
LBY	EHD	EAR

SUBMITTED
CHIEF, HYD. ENG. SECTION
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, COMP. R. BASIN SECTION
APPROVAL RECOMMENDED
CHIEF, PLANN'G & R.P.T.S BRANCH

WATER RESOURCES STUDY
REPLACEMENT-OLD SLATER MILL DAM
STREAMBANK PROTECTION
PLAN AND DETAILS

BLACKSTONE RIVER — RHODE ISLAND
APPROVED — DATE
CHIEF, ENGINEERING DIVISION
SCALE AS NOTED — SPEC NO
DRAWING NUMBER
SHEET 2 of 2

PLATE D 3

2

TABLE 2-9

FIRST ALTERNATIVE

FIRST COST - MODIFICATION OLD SLATER MILL DAM
(June 1976 - Price Level)

Description	Amount	Total
Lands and Damages	$ 118,800	$ 118,800
Modification of Dam	468,000	
Channel Work	531,400	
Walls	1,007,900	
Sluice Gate at Old Slater Mill	100,000	
Interior Drainage	730,800	
Floodproofing Buildings	1,200,000	
	4,038,100	
Engineering and Design (17%)	686,500	
Supervision and Administration (11%)	444,200	
	$5,168,000	5,168,000
TOTAL PROJECT FIRST COST		$5,287,000

TABLE 2-10

SECOND ALTERNATIVE

FIRST COSTS - OLD SLATER MILL - CHANNEL IMPROVEMENTS ONLY
(June 1976 - Price Level)

Description	Amount	Total
Lands and Damages	$ 118,800	$ 118,800
Channel Work	531,400	
Walls	1,007,900	
Sluice Gate at Old Slater Mill	100,000	
Interior Drainage	730,800	
Floodproofing Buildings	1,200,000	
	3,570,000	
Engineering and Design (17%)	606,900	
Supervision and Administration (11%)	392,700	
	$4,569,700	4,569,700
TOTAL PROJECT FIRST COST		$4,688,500

TABLE 2-11

ANNUAL CHARGES
FIRST ALTERNATIVE

OLD SLATER MILL DAM -MODIFICATION
(50-Year Life)
(June 1976-Price Level)

FEDERAL INVESTMENT		
Federal First Cost	$5,168,800	
Interest During Construction (6 3/8%)	329,500	
Total Federal Investment	5,498,300	
FEDERAL ANNUAL CHARGE		
Interest (6 3/8%)	350,500	
Amortization	16,660	
Total Federal Annual Charge		$367,160
NON-FEDERAL INVESTMENT		
Lands, Easements, Rights of Way	118,800	
Total Non-Federal First Cost	118,800	
Interest During Construction (6 3/8%)	7,570	
Total Non-Federal Investment	126,370	
NON-FEDERAL ANNUAL CHARGE		
Interest (6 3/8%)	8060	
Amortization	380	
Maintenance & Operation	2,500	
Interim Replacements	1,000	
Loss of Productivity of Land	-	
Total Non-Federal Annual Charge		$ 11,940
TOTAL ANNUAL CHARGE		$379,100

TABLE 2-12

ANNUAL CHARGES
SECOND ALTERNATIVE

OLD SLATER MILL DAM - CHANNEL - IMPROVEMENTS ONLY
(100-Year Life)
(June 1976 - Price Level)

FEDERAL INVESTMENT		
Federal First Cost	$4,569,700	
Interest During Construction (6 3/8%)	291,300	
Total Federal Investment	$4,861,000	
FEDERAL ANNUAL CHARGE		
Interest (6 3/8%)	309,900	
Amoritzation	630	
Total Federal Annual Charge		$310,530
NON-FEDERAL INVESTMENT		
Lands, Easements, Rights of Way	118,800	
Total Non-Federal Investments	118,800	
Interest During Construction (6 3/8%)	7,570	
Total Non-Federal Investment	126,370	
NON-FEDERAL ANNUAL CHARGE		
Interest (6 3/8%)	8060	
Amortization	20	
Maintenance & Operation	1,000	
Interim Replacements	1,000	
Loss of Productivity of Land	-	
Total Non-Federal Annual Charge		10,080
Total Annual Charges		320,610

Modification of Sayles Finishing Company Dam

a. General - The channel improvement project would be located approximately 80 feet downstream from the Broad Street Bridge in Central Falls, Rhode Island. The plan of protection would provide for modifying the existing dam by lowering and replacing the present dam crest with bascule type gates. The communities of Lincoln, Cumberland and Central Falls, in conjunction with the State of Rhode Island have proposed a conservation-recreation site for the Valley Falls Pond area upstream from the dam. Installation of gates would maintain present upstream water levels and be consistent with this planning and also would permit the passage of floodflows. Stone slope protection would be placed at locations immediately upstream from the dam to prevent erosion of building and bridge foundations. Upstream retaining walls would have to be raised and an earth berm constructed to prevent overtopping from expected floodflows (see Plate D-4).

b. Social and Economic Considerations - The modification would reduce damages for several industrial and commercial establishments, and public facilities lying upstream.

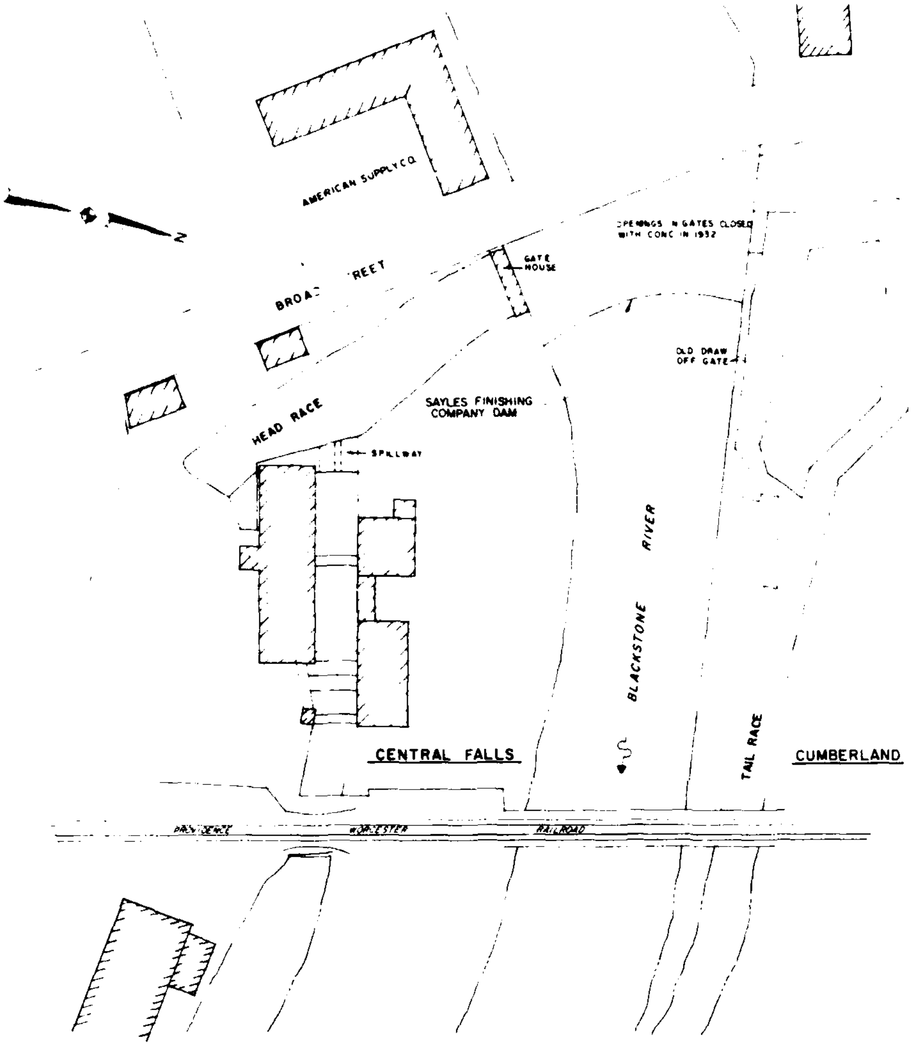
Construction activities at the site would generate air quality, noise, and traffic impacts. The construction period would last approximately one year. Use of access routes to the construction site would effect traffic flows in this already congested area of downtown Central Falls. Approximately two acres would be taken in temporary land easements during the construction period for the storage of equipment and materials.

Of particular concern in this project area and in regard to the project is the Valley Falls Pond area upstream from the dam which has been acquired as a conservation-recreation area by communities in conjunction with the State of Rhode Island. Installation of the bascule gates would maintain present upstream water levels and would not interfere with the conservation-recreation plan.

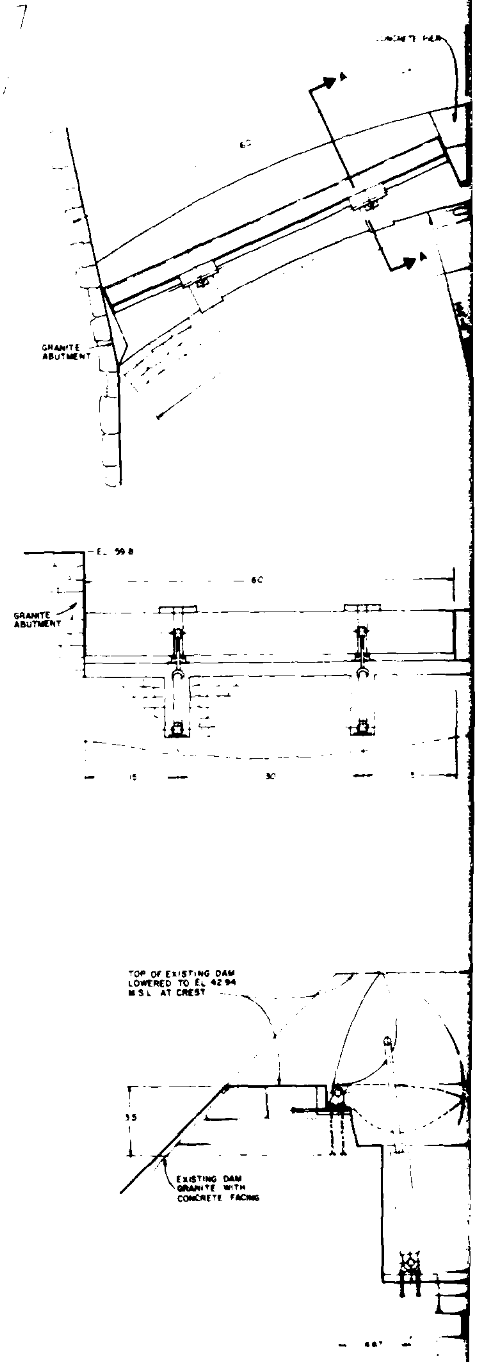
c. Description of Structure

Bascule Gates - The gates considered for this modification would be the "Pelican" style as used in the Slater Mill modification. There would be three leaves, 60'0" x 7'0". The leaves would be 7'0" high in order to maintain the original crest elevation (El. 49.94 NGVD), but when activated they would lower to a fully open position, providing a modified crest elevation of 42.94 NGVD to pass floodflows.

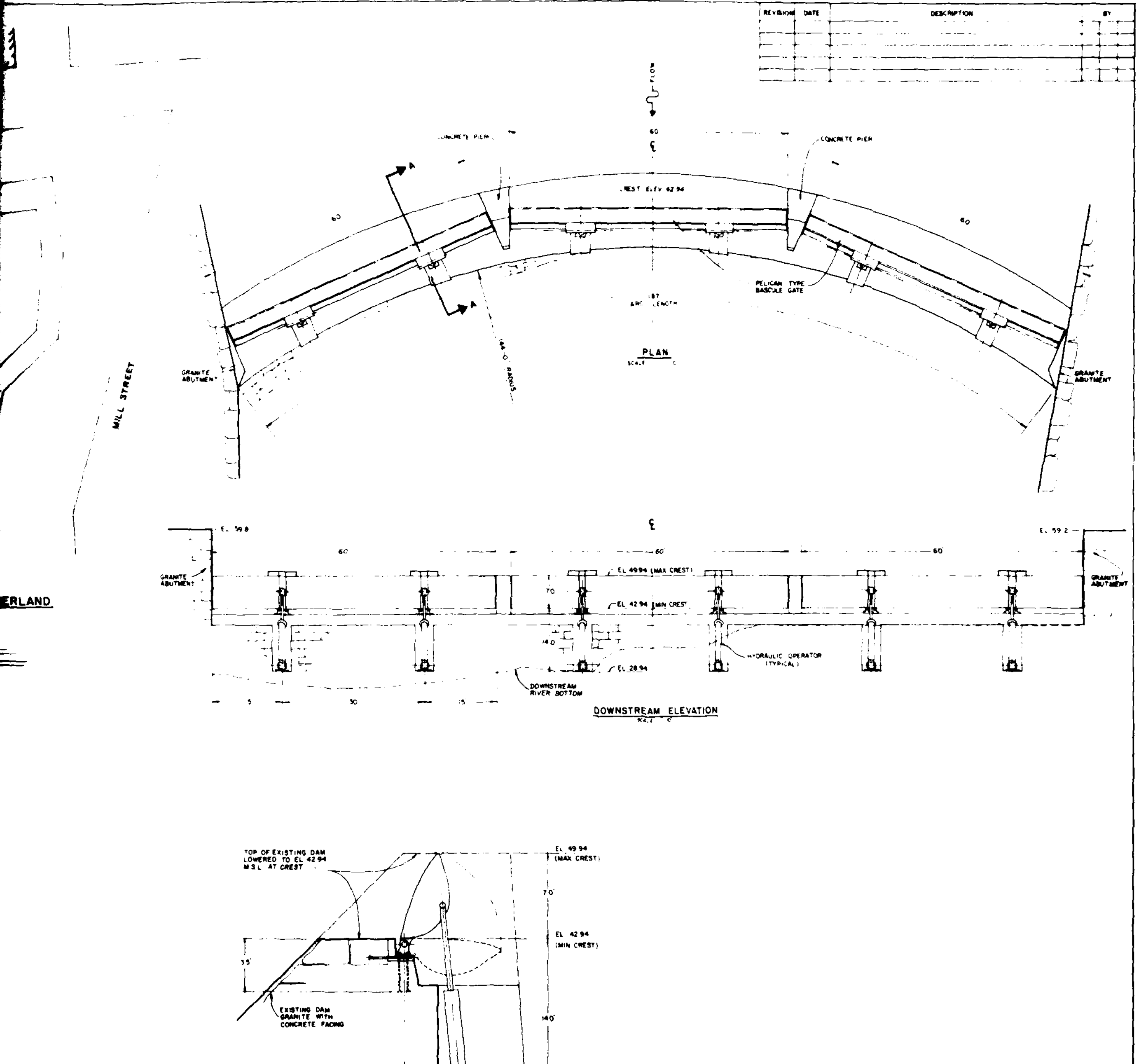
Channel Work - Channel improvement would, in general, consist of placing stone slope protection along existing building and bridge foundations and retaining walls that abut the river's edge to protect them from



PLAN
SCALE 1" = 50'



TYPICAL SECTION A-A
NOT TO SCALE



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DES. BY E.A.R. · DR. BY R.L.P. · CK. BY L.B.T.	WATER RESOURCES STUDY REPLACEMENT-SAYLES FINISHING CO. DAM GENERAL PLAN & DETAILS
SUBMITTED · CHIEF, HYD. ENG. SECTION	BLACKSTONE RIVER · RHODE ISLAND
REVIEWED · PROJECT ENGINEER	APPROVED · DATE
APPROVAL RECOMMENDED · CHIEF, COMP. & BASIN SECTION	CHIEF, ENGINEERING DIVISION
APPROVAL RECOMMENDED · CHIEF, PLANN. & RPTS. BRANCH	SCALE AS NOTED · SPEC. NO. · DRAWING NUMBER · SHEET 1 of 2

PLATE D 4

erosion. A total of approximatley 860 feet of protection would be provided on both streambanks upstream of the Sayles Finishing Dam. Protective stone would be placed on supporting bedding material on a 1-foot vertical to a 2-foot horizontal slope.

Walls - Existing retaining walls along the streambank would be raised to prevent overtopping. In general, the construction would match the existing structure. A total of 100 feet of wall would have to be placed upstream of the Broad Street Bridge on the south bank to prevent flooding in that area.

d. Estimates of Cost

First Costs - A detailed breakdown of first costs for the project is shown in Table 2-13.

Annual Charges - The estimate of Federal annual charges is based on interest at 6-3/8 percent (FY 77) on the Federal investment plus the amount required to amortize the investment over the assumed 50-year life of the project. Non-Federal interest and amortization charges were computed in a similar manner at the same interest rate. Non-Federal charges also include amounts for maintenance and operation of the project and interim replacement of equipment having an estimated life of less than 50-years. The derivation of annual charges is given in Table 2-14.

e. Project Formulation - Annual benefits accruing to the project are estimated to be $25,000. Annual charges are estimated at $102,860. The combined economic and environmental benefit/cost ratio is 0.24 to 1, resulting in an unfavorable project.

Uxbridge Local Protection Project

a. General - This local protection project would be located along the east bank of the Mumford River in Uxbridge, Massachusetts. It would form an enclosure with dikes and floodwalls to protect the firm of Emile Bernat & Sons. The plan of protection would provide for the construction of approximately 245 feet of earth dikes, 985 feet of concrete floodwall, a vehicular gate, two pumping stations and other appurtenant works (see Plate D-6).

b. Social and Economic Considerations - The project would prevent inundation of Depot Street behind the Bernat factory. The Depot Street river crossing would, however, continue to be inundated during major floods. The project would not lower downstream flood stages and would not protect any developable land and would therefore not induce new development.

TABLE 2-13

FIRST COSTS - REPLACEMENT SAYLES FINISHING CO. DAM

(1976 - Price Levels)

Description	Amount	Total
Lands and Damages	$ 7,920	$ 7,920
Modification of Dam and Bascule Gate	1,033,560	
Channels	44,358	
Walls	8,735	
	1,086,653	
Engineering and Design (17%)	184,732	
Supervision and Administration (11%)	119,525	
Subtotal	1,390,910	1,390,910
TOTAL PROJECT FIRST COST		$1,398,830

TABLE 2-14

ANNUAL CHARGES

SAYLES FINISHING COMPANY DAM -MODIFICATION
(50-Year Life)
June 1976 - Price Level

FEDERAL INVESTMENT		
Federal First Cost	$1,390,910	
Interest During Construction (6 3/8%)	88,670	
Total Federal Investment	1,479,580	
FEDERAL ANNUAL CHARGE		
Interest (6 3/8%)	94,320	
Amortization	4,480	
Total Federal Annual Charge		$ 98,800
NON-FEDERAL INVESTMENT		
Lands, Easements, Relocations	7,920	
Total Non-Federal Investment	7,920	
Interest During Construction (6 3/8%)	500	
Total Non-Federal Investment	8,420	
NON-FEDERAL ANNUAL CHARGES		
Interest (6 3/8%)	535	
Amortization	25	
Maintenance & Operation	2,500	
Interim Replacement	1,000	
Loss of Productivity of Land	-	
Total Non-Federal Annual Charge		4,060
Total Annual Charges		$102,860

Construction activities at the site of the Uxbridge project would generate air quality, noise, and traffic impacts. The impact of the construction activities would be lesser in this industrial area than if it were a residential and/or commercial area. Although access routes in all directions are heavy duty roads, there are some residences that could be adversely affected by the noise and exhaust of substantial truck traffic during the construction period. The general area immediately surrounding the factory/construction area includes the downtown center of Uxbridge which would become more congested with increased heavy truck traffic.

c. Project Formulation - Annual benefits accuring to the project are estimated to be $77,600. Annual charges are estimated at $116,700, resulting in an 0.66 to 1.0 economic benefit/cost ratio and making this an economically unjustified project. These costs are the original 1965 project costs increased by the Engineering News Record factors to reflect current prices. In addition, the Bernat Company has implied it cannot affort to put any funds toward the protection project. The firm has already developed its own flood damage reduction plan and the town of Uxbridge has joined the flood insurance program. The project also does not produce environmental benefits as well as a favorable benefit/cost ratio and was not considered further.

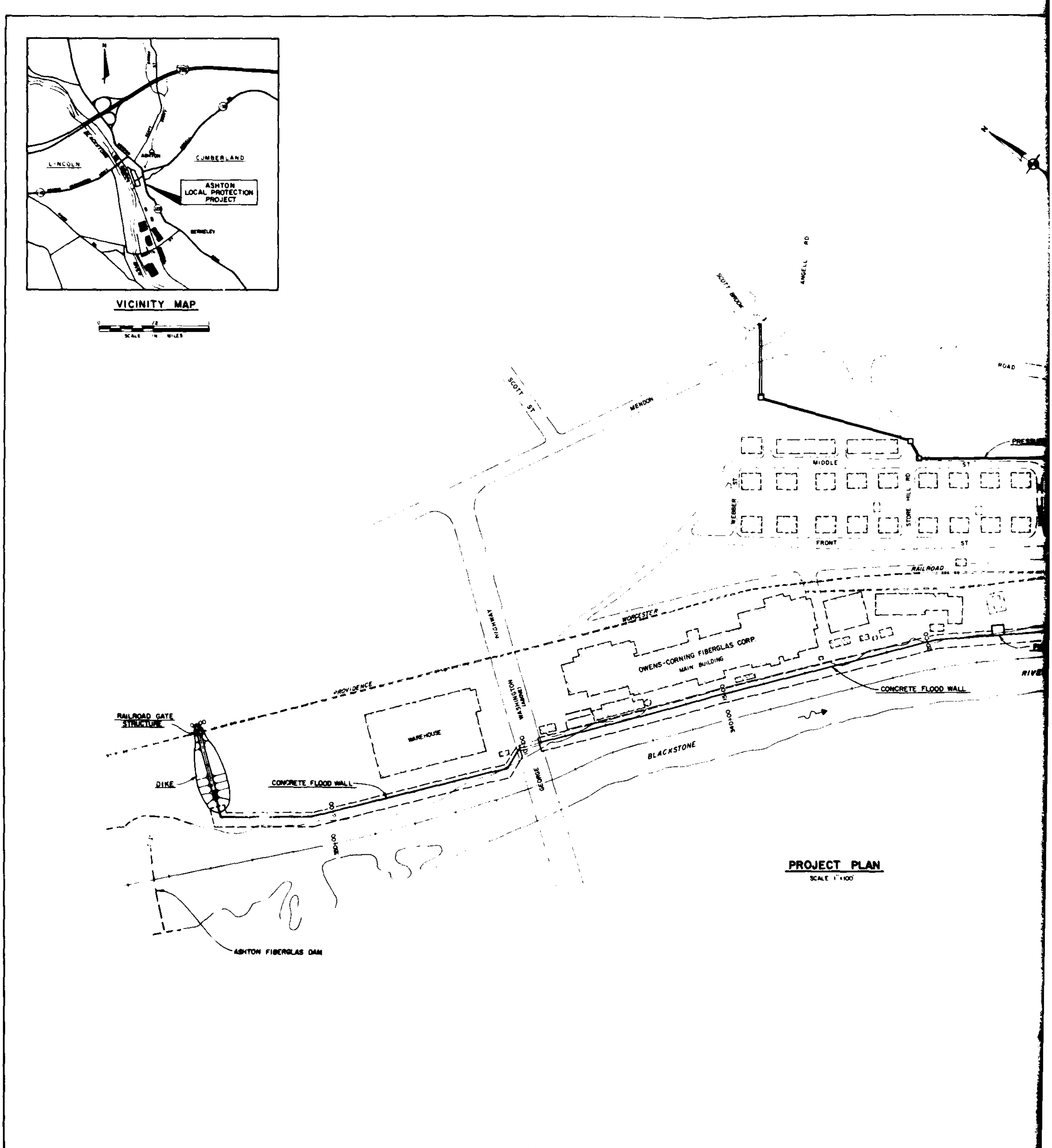
For further information on this project, see the October 1965 Uxbridge Local Protection Project Report.

Ashton Local Protection Project

a. General - The local protection project recommended to handle the runoff from approximately 1,050 acres would be located along the easterly bank of the Blackstone River in Cumberland, Rhode Island. It would extend from river station 330+00 (2.5 miles above Valley Falls Pond, Central Falls, Rhode Island) to station 350+00 (500 feet downstream from the Ashton Fiberglas Dam). The plan of protection would provide for construction of 2,300 feet of concrete floodwalls, 335 feet of earth dike, two railroad stoplog structures, a pumping station, interior drainage, twin pressure conduits and other appurtenant works. The project would provide protection against the Standard Project Flood for the 10 acres of land within the U-shaped facility (see Plate D-5).

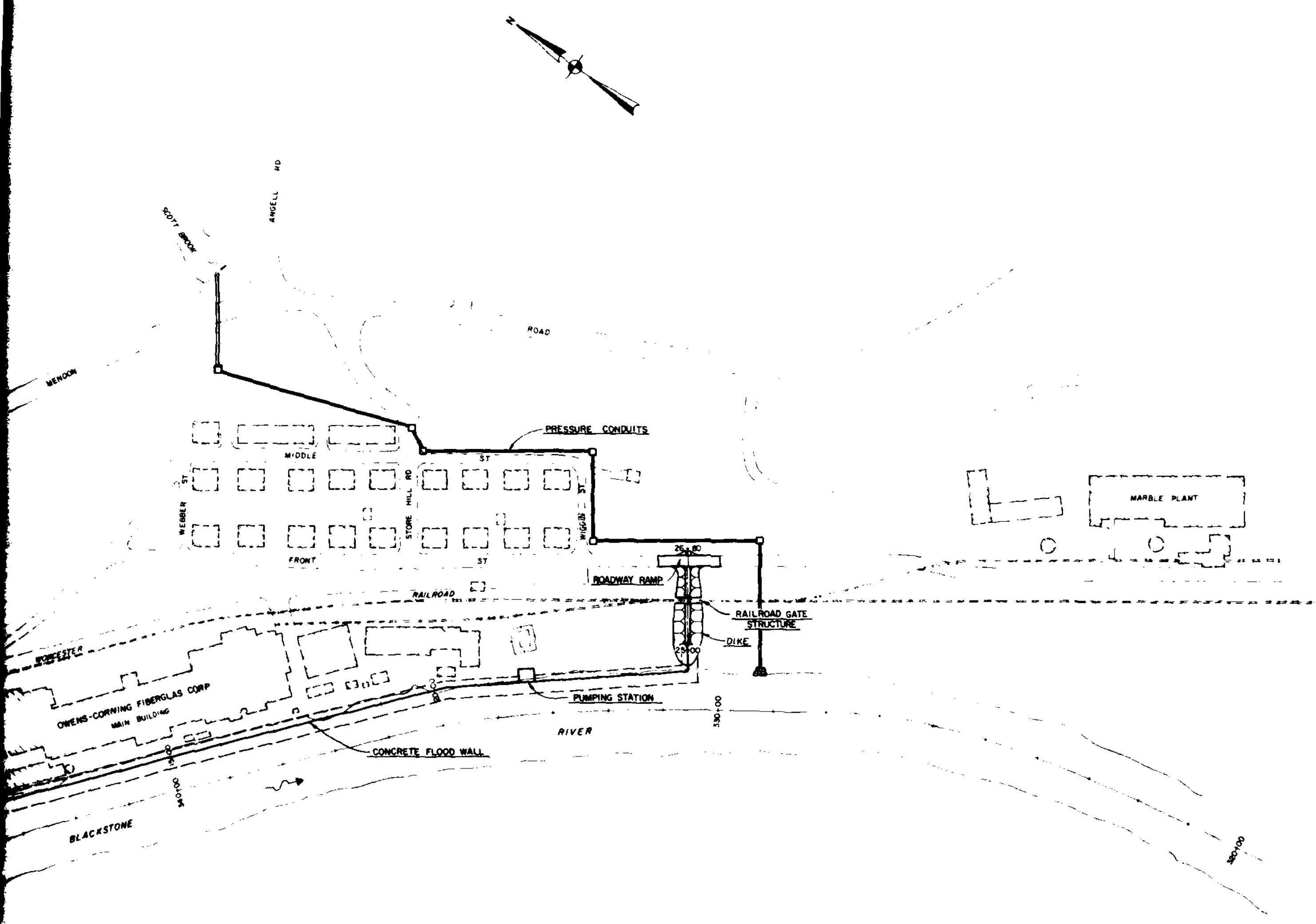
b. Social and Economic Considerations - The Ashton Local Protection Project would provide complete flood protection for the Owens-Corning Fiberglas plant on the Blackstone River. No additional vacant or underutilized land would be protected by the project; no significant land use changes would be anticipated as a result of this alternative. The project would prevent damages to the Owens-Corning plant.

The Owens-Corning plant plays a significant role in the economy of Cumberland. Its main building, adjacent to the project area is a large four story brick mill building estimated to be in excess of 100-years



LINCOLN
CUMBERLAND
ASHTON
ASHTON LOCAL PROTECTION PROJECT
BERKELEY
VICINITY MAP
SCALE IN MILES
SCOTT BROOK
ANGELL RD
SCOTT ST
MENDON
ROAD
MIDDLE ST
WEBBER ST
STONE HILL RD
FRONT ST
RAILROAD
WORCESTER
PROVIDENCE
OWENS-CORNING FIBERGLAS CORP. MAIN BUILDING
HIGHWAY
WASHINGTON
GEORGE
WAREHOUSE
RAILROAD GATE STRUCTURE
DIKE
CONCRETE FLOOD WALL
CONCRETE FLOOD WALL
BLACKSTONE
RIVER
ASHTON FIBERGLAS DAM
PROJECT PLAN
SCALE 1"=100'

REVISION	DATE	DESCRIPTION	BY



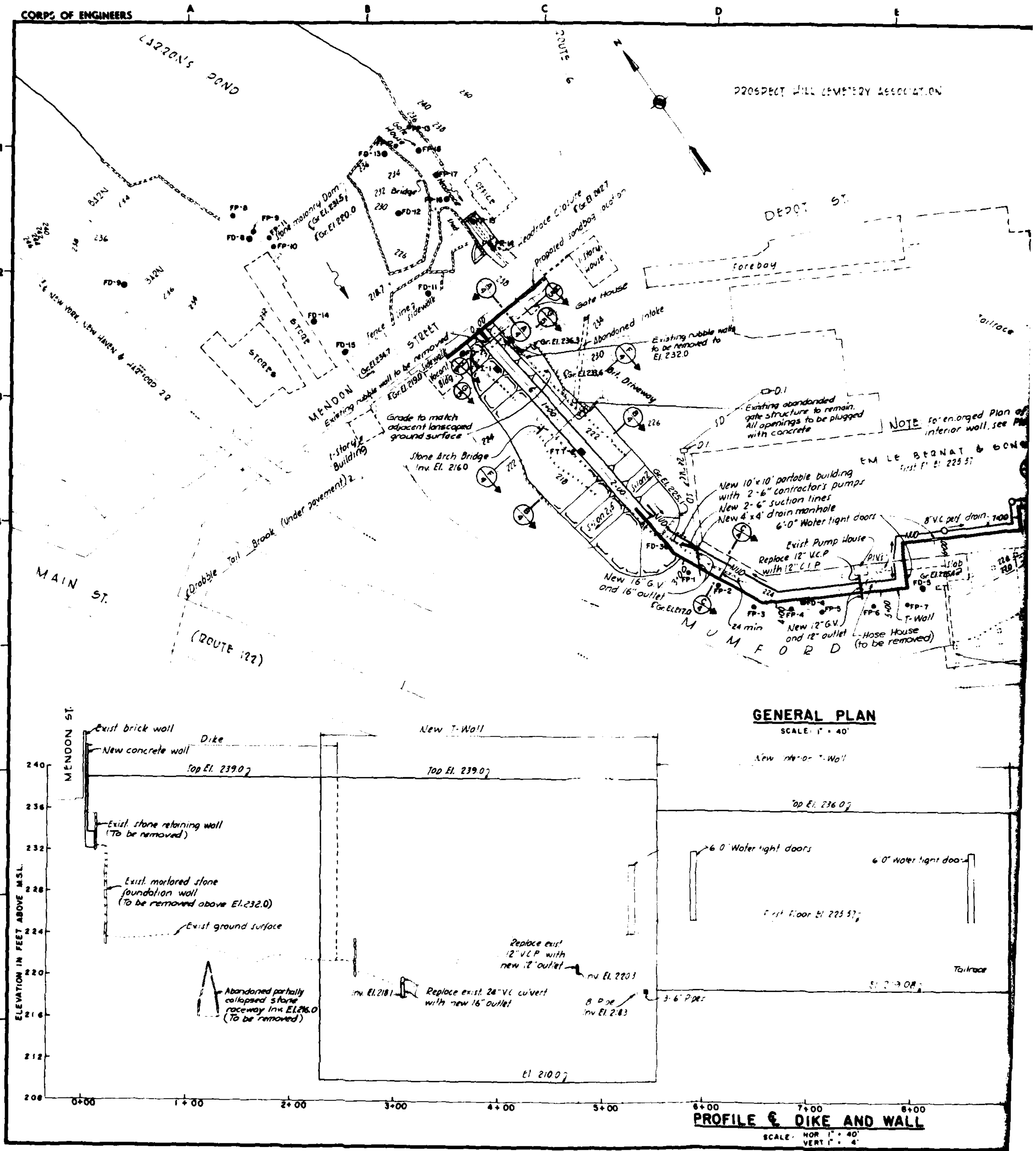
PROJECT PLAN
SCALE 1"=100'

GRAPIC SCALE
1"=100'-0"

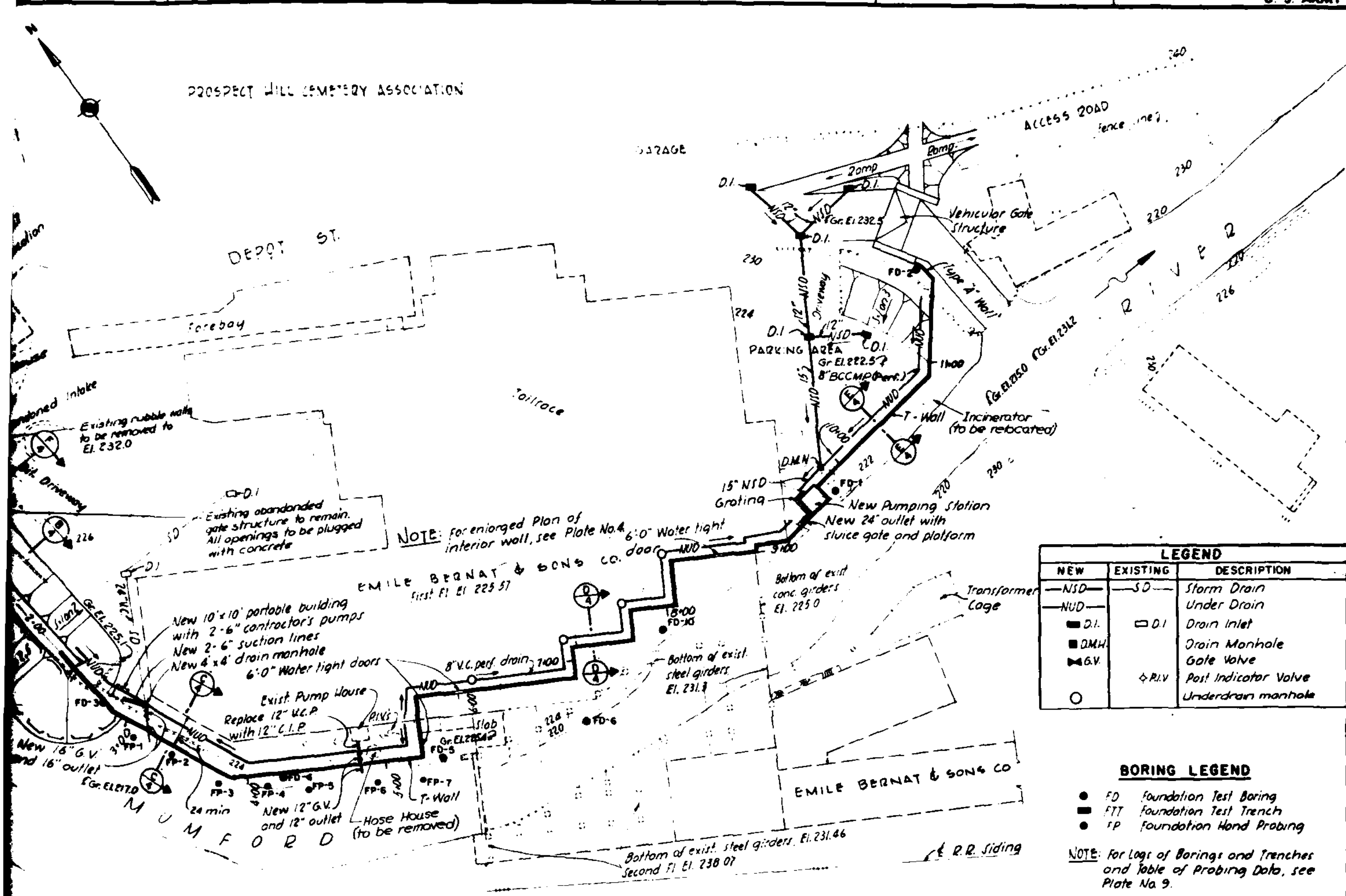
CE MAGUIRE, INC. ARCHITECTS ENGINEERS PLANNERS PROVIDENCE, R.I. WALTHAM, MASS. NEW BRITAIN, CONN.	DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.
DES BY EHD / DR BY EHD / CK BY EAR	WATER RESOURCES STUDY ASHTON LOCAL PROTECTION PROJECT PROJECT PLAN
SUBMITTED / CHIEF, HYD. ... SECTION / REVIEWED / PROJECT ENGINEER / APPROVAL RECOMMENDED / CHIEF, COMP. & BASIN SECTION / APPROVAL RECOMMENDED / CHIEF PLANS & SPECS BRANCH	BLACKSTONE RIVER — RHODE ISLAND APPROVED: DATE CHIEF ENGINEERING DIVISION
	SCALE 1"=100 — SPEC NO DRAWING NUMBER SHEET 1 of 4

PLATE D-5

2


CORPS OF ENGINEERS
A
B
C
D
E
1
2
3
4
5
6
7
8
PROSPECT HILL CEMETERY ASSOCIATION
ROUTE 6
DEPOT ST.
Foreboy
Gate House
Office
Proposed sandbag location
Headrace Closure
Stone masonry Dam
Bridge
Store
Stores
N.Y., NEW YORK, NEW HAVEN & HARTFORD R.R.
MENDON STREET
Existing rubble wall to be removed
Sidewalk
Fence lines
Vacant Bldg
Abandoned intake
Existing rubble walls to be removed to El. 232.0
Existing abandoned gate structure to remain. All openings to be plugged with concrete
NOTE For enlarged Plan of interior wall, see
EMILE BERNAT & SONS
Grade to match adjacent landscaped ground surface
1-story Building
Stone Arch Bridge Inv. El. 216.0
Drabble Tail Brook (under pavement)
MAIN ST.
(ROUTE 122)
New 10'x10' portable building with 2-6" contractor's pumps with 2-6" suction lines
New 2-6" drain manhole
New 4'x4' drain manhole
6'-0" Water tight doors
Exist. Pump House
Replace 12" V.C.P. with 12" C.I.P.
8" V.C. perf. drain
New 16" G.V. and 16" outlet
New 12" G.V. and 12" outlet
Hose House (to be removed)
T-Wall
MUMFORD
Tailrace
GENERAL PLAN
SCALE: 1" = 40'
MENDON ST.
Exist brick wall
New concrete wall
Dike
New T-Wall
Top El. 239.0
New interior T-Wall
Top El. 236.0
Exist. stone retaining wall (To be removed)
Exist. mortared stone foundation wall (To be removed above El. 232.0)
Exist ground surface
6'0" Water tight doors
6'0" Water tight doors
Exist. floor El. 225.57
Replace exist. 12" V.C.P. with new 12" outlet
Inv. El. 220.3
Inv. El. 218.1
Replace exist. 24" V.C. culvert with new 16" outlet
8" Pipe Inv. El. 218.3
3-6" Pipes
Abandoned partially collapsed stone raceway Inv. El. 216.0 (To be removed)
El. 210.0
Tailrace
ELEVATION IN FEET ABOVE M.S.L.
240
236
232
228
224
220
216
212
208
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
PROFILE € DIKE AND WALL
SCALE: HOR. 1" = 40' VERT. 1" = 4'

U. S. ARMY



GENERAL PLAN

SCALE: 1" = 40'

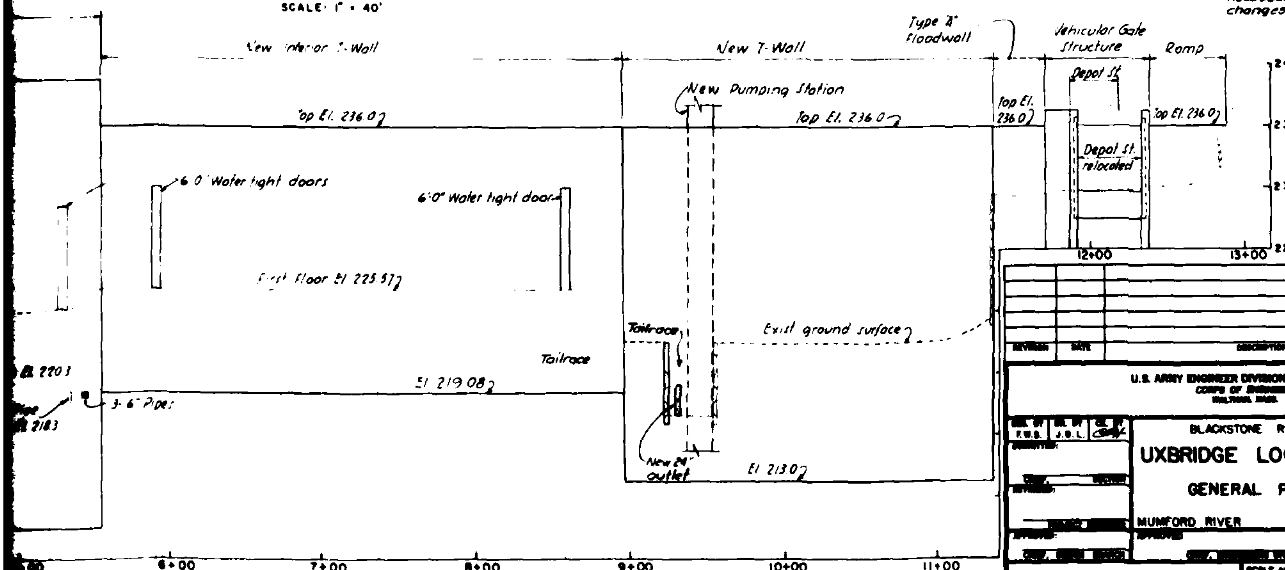
LEGEND		
NEW	EXISTING	DESCRIPTION
—NSD—	—SD—	Storm Drain
—NUD—		Under Drain
D.I.	D.I.	Drain Inlet
D.M.H.		Drain Manhole
G.V.		Gate Valve
	P.I.V.	Post Indicator Valve
○		Underdrain manhole

BORING LEGEND

- FD Foundation Test Boring
- FTT Foundation Test Trench
- FP Foundation Hand Probing

NOTE: For Logs of Borings and Trenches and Table of Probing Data, see Plate No. 9.

NOTE: Stationing to be revised as necessary because of alignment changes.



PROFILE ℄ DIKE AND WALL

SCALE: HOR. 1" = 40' VERT. 1" = 4'

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS

BLACKSTONE RIVER FLOOD CONTROL

UXBRIDGE LOCAL PROTECTION

GENERAL PLAN & PROFILE

MUMFORD RIVER MASSACHUSETTS

OCTOBER 1965

PLATE D-6

old. Several accessory buildings constructed within the past ten years supplement the main building. No buildings of the Owens-Corning complex would be acquired for project purposes. However, a six foot security fence and some propane tanks in this area would be affected by the project. Also, approximately six acres of Owen-Corning owned land would be taken for project purposes.

Construction activities would be expected to create impacts of a temporary nature. The project area would be subjected to increased levels of air and noise pollution. Access to the project site would be through the Owens-Corning complex and could hinder the movement of the plant's trucks and outdoor equipment or supplies. Approximately two acres of land would be taken for temporary easement for the two year construction period. A temporary water easement of approximately one-half acre would be needed for cofferdam construction. Other temporary impacts to be experienced during the construction period would depend on the types and sources of construction materials.

c. Estimates of Costs

First Costs - A detailed breakdown of first costs for the project is shown in Table 2-15.

TABLE 2-15

FIRST COST - ASHTON LOCAL PROTECTION PROJECT
(June 1976 - Price Level)

Description	Amount	Total
Lands and Damages	$ 72,000	
Relocations	30,750	
		102,750
Site Preparation and Stream Control	1,206,000	
Levees	39,620	
Floodwalls	3,675,958	
Stop Log Structures	50,300	
Front Steel Ramp	10,620	
Drainage	56,599	
48" Pressure Conduits	324,005	
Pumping Station	329,000	
Sluice Gate Structure	54,000	
	5,746,102	
Contingencies (20%)	1,149,218	
	6,895,320	
Engineering and Design (15%)	1,034,300	
Supervisioin and Administration (10%)	689,530	
Subtotal	8,619,150	8,619,150
TOTAL PROJECT FIRST COST		$8,712,900

Annual Charges - The estimate of Federal annual charges is based on interest at 6-3/8 percent (FY 77) on the Federal investment plus the amount required to amortize the investment over the assumed 100-year life of the project. Non-Federal interest and amortization charges were computed in a similar manner at the same interest rate. Non-Federal charges also include amounts for maintenance and operation of the project and interim replacement of equipment having an estimated life of less than 100-years. The derivation of annual charges is given in Table 2-16.

d. Project Formulation - Annual benefits accruing to the project are estimated to be $288,120. Annual charges are estimated to be $596,875 resulting in an economic benefits/cost ratio of 0.48 to 1.0. The project does not produce any environmental benefits and therefore was not considered further.

e. Other Plans Studied - An alternative to bypassing this runoff by pressure conduit was considered in an investigation to determine the capacity required to divert this flow through the existing channel of Scott Brook. It was found that the 10-year storm event would require an excessive channel width to carry the flow and therefore was not considered further.

ASSESSMENT AND EVALUATION OF DETAILED PLANS

Berkeley Local Protection Structural Project - Plan A

General - The structural local protection project at Berkeley would be located along the east bank of the Blackstone River in Cumberland, Rhode Island. It would extend from river station 280+00 (approximately two miles above Valley Falls Pond) to river station 320+00, a distance of about 4,000 feet. The plan of protection would provide for construction of 3,800 feet of earth dikes, 1,450 feet of concrete floodwalls, a pumping station, a vehicular ramp over the dike at Martin Street, a vehicular gate, two railroad gates, interior drainage and other appurtenant works. (See Main Report, Plates 3 and 4.)

Impact Assessment - Plan A

Economic Impacts and Social Impacts - The Berkeley Local Protection Project (LPP) would offer SPF flood protection to approximately 70 acres along the Blackstone River in Cumberland, Rhode Island, which is occupied by the Berkeley Industrial Park, a Cumberland Water Supply Well, and the Berkeley Oval Park. Detailed discussion of the economic analysis is provided in Appendix 7, Economics and summarized as follows for Plan A: (June 1981 Price Level)

TABLE 2-16

ANNUAL CHARGES

ASHTON LOCAL PROTECTION PROJECT
(100-Year Life)
(June 1976 Price Level)

FEDERAL INVESTMENT		
Federal First Cost	$8,619,150	
Interest During Construction (6 3/8%)	549,470	
Total Federal Investment	9,168,620	
FEDERAL ANNUAL CHARGE		
Interest (6 3/8%)	584,500	
Amortization	1,190	
Total Federal Annual Charge		$585,690
NON-FEDERAL INVESTMENT		
Lands, Easements, Relocations	102,750	
Total Non-Federal Investment	102,750	
Interest During Constrction (6 3/8%)	6,550	
Total Non-Federal Investment	109,300	
NON-FEDERAL ANNUAL CHARGE		
Interest (6 3/8%)	6,970	
Amortization	15	
Maintenance & Operations	2,500	
Interim Replacements	1,700	
Loss of Productivity of Land	-	
Total Non-Federal Annual Charge		11,185
TOTAL ANNUAL CHARGES		$596,875

Average Annual Benefits	$698,100
Average Annual Costs	517,300
Average Annual Net Benefits	$180,800
Plan A, Benefit-to-Cost Ratio	1.4 to 1
	(1.35)
Project First Cost	$6,[illegible]

Along with damages prevented, the LPP would increase the flood problem experienced upstream, increasing damages to the Owens-Corning Fiberglas plant as well as to a single residence lying on the other side of the Blackstone opposite Owens-Corning. Approximately 20 acres currently lie vacant. The flood protection offered by this project would make the vacant acreage, which already has access to utilities, more appealing for industrial development.

Construction activities at the site would generate air quality, noise and traffic impacts. These impacts are not expected to be significant because this is an industrial area; however, the access routes are residential. Of particular concern is the ball park which may be taken as a temporary easement during construction. A portion of the ball park could be permanently lost with the placement of the dike ramp as presently proposed.

Environmental Impacts - The flood protection by the Berkeley project will provide flood damage protection to the Blackstone Valley sewerline, a water supply pumping station for the town of Cumberland, a private well owned by Owens-Corning Fiberglass, and 5,000 feet of right-of-way of the Providence and Worcester Railroad.

More detailed descriptions and analyses of this project will be presented in following appendices.

Evaluation and Trade-Off Analysis - A primary shortrun effect of the Berkeley project would be the availability of increased employment for many unskilled and semi-skilled laborers during the construction phases of this project. The Berkeley project would offer protection for some flood prone areas. Such protection could result in economic and social enhancement of these localities. The reduction of damages from floods would yield great economic benefits, especially to industry and may halt the flight of manufacturing jobs. It may also encourage industrial growth in the area.

Mitigation Requirements

Wildlife Habitat - Construction of the dike and wall will impact 11 acres for new structures, plus another 2.5 acres for construction rights-of-way. The resulting loss of wildlife habitat will be mitigated by planting the landward side of the dike with plants suitable for wildlife habitat. Temporary rights-of-way will be revegetated by topsoiling and seeding or replanting where appropriate.

Aesthetic Impact - The project will result in the loss of riverbank vegetation along 4,000 feet of the east bank of the Blackstone River. However, only a small portion of this area is now heavily wooded. Visual impact from vegetation loss and construction of the dikes and wall will be greatest from the vantage point of Martin Street and to a lesser extent from the Blackstone Canal towpath (proposed trail route in the Blackstone Linear Park). Existing vegetation on the west bank of the river between the towpath and the river helps to screen the view of the east bank. The visual impact from Martin Street will be mitigated in part by carefully protecting trees not to be removed for construction, and by replacing new trees and shrubs beyond the toe of the landward side of the dike at Martin Street.

Town Recreation Area - Plan A would necessitate the realignment of the access road to the Health Tex building, resulting in the loss of a baseball field in the adjacent town recreation area. Further study of alternative access routes to Health Tex will be carried out in the Phase I GDM. If no other route is found to be feasible, the loss of this recreation area will be mitigated by replacement in kind, either through improved facilities on the remaining land, or through acquisition of a new site.

Impact on Blackstone Canal - Construction of Plan A's protection structures may cause increased erosion of the west bank of the Blackstone River, with questionable impact on the Blackstone Canal. Further engineering studies in the Phase I GDM would analyze the need to realign the proposed dike layout or provide limited stone slope protection on the west bank.

Plan A - Summary

Investigations to mitigate the impacts of Plan A on the Owens-Corning Fiberglas plant were terminated in the summer of 1981. When discussed in the Main Report, the local cost for this plan was determined to be beyond the resources of the town. Although the plan demonstrated potential economic and environmental feasibility, and was supported under traditional cost sharing, it was not implementable under new cost sharing policies. The Nonstructuctural Plan B, following, appeared to be the only potential solution to provide some flood protection to the Berkeley Industrial Park. The "PLAN SELECTION," section later in report, discusses implementation and cost sharing.

Berkeley Local Protection Nonstructural - Plan B

General - Plan B provides 100 year frequency flood protection to three industrial buildings and the town pumping station, located in the Industrial Parks. The plan involves floodproofing the four structures by waterproofing walls, and flood shields for doors and openings and ring walls around unloading areas as described in the Main Report. (See Main Report, Plate 5.)

Impact Assessments

Appendix 7 presents the detailed economic assessment for Plan B, summarized as follows: (June 1981 price level)

Plan B - Summary Economic Analysis
(In $1000)

Average Annual	Health-Tex	Roger Wm's	Okonite Co.	Pump Sta.
Benefits:	$200.3	$77.8	$21.5	$0.8
Costs (20 yr. life):	$ 50.6	$60.5	$ 6.1	$0.8
Net Benefits:	$149.7	$17.3	$15.4	0
BCR:	4.0	1.3	3.5	1.0
First Cost:	$521.8	$624.1	$62.5	$8.5

Since each structure's Benefit-to-Cost Ratio (BCR) equals or exceeds 1.0, all increments of the plan are economically justified. Their are no significant adverse environmental or social impacts associated with the plan, thus no mitigation measures are required.

System of Accounts - The System of Accounts (as required by "Principles and Standards for Planning Water and Related Land Resources," published by the Water Resources Council, and Engineering Regulation 1105-2-921 "Feasibility Reports: System of Accounts") reflects the overall beneficial and adverse effects of the selected alternatives. Effects can be readily discerned, and trade-offs between alternative plans can be compared. This is an integral part of the planning process and leads to the selection of the alternative plan that best meets the goals and objectives of National Economic Development (NED), Environmental Quality (EQ), Social Well-Being (SWB) and Regional Development (RD). This summary of accounts is shown in Table 2-17.

The System of Accounts (SA) displays information concerning the geographic regions in which a significant portion of any beneficial or adverse impacts would occur. The following paragraphs define the various regions analyzed.

Within the Watershed - This constitutes the entire drainage area within the Blackstone River Basin. The watershed consists of 29 towns and cities in Massachusetts and 9 communities in Rhode Island.

(SMSA) - This study encompasses the Providence-Pawtucket-Warwick SMSA, which includes 23 Rhode Island cities and towns, plus 10 contiguous Massachusetts cities and towns.

TABLE 2-17
SYSTEM OF ACCOUNTS

Accounts	Footnotes (See Text "System of Accounts)	PLAN A BERKELEY LOCAL PROTECTION PROJECT LOCATION OF IMPACTS: Within the Watershed	PLAN A: Within the Rest of the Nation	PLAN B BERKELEY NONSTRUCTURAL PLAN LOCATION OF IMPACTS: Within the Watershed		PLAN B: Within the Rest of the Nation		WITHOUT CONDITIONS LOCATION OF IMPACTS: Within the Watershed	WITHOUT CONDITIONS: Within the Rest of the Nation
1. National Economic Development									
				Health-Tex	Roger Williams Foods	Okonite Co.	Town Pump Station		
Flood Control (NED) Benefits		$698,100		$200,300	$77,800	$21,500	$800		
Total Annual Costs		$517,300		$50,600	$60,500	$6,100	$800		
Net NED Benefits		$180,800		$149,700	$17,300	$15,400	$-0-		
B/C Ratio		1.35		4.0	1.3	3.5	1.0		
2. Environmental Quality									
Natural Channel Bottom Lost (acres)	1,6,8,9	0.25 acres	Negligible	None		None		None	None
Impound Channel Bottom Grained (acres)	1,6,8,9	None	None	None		None		None	None
Floodplain Lost	1,6,8,9	80 acres	None	21.2 acres		None		None	None
Effect on Flora and Fauna	1,5,8,9	Flora loss mitigated by new plantings	None	None		None		None	None
Effect on Water Quality in Blackstone River	1,5,8,9	Slightly Negative	None	None		None		None	None
Effect on Air and Noise Pollution	1,5,8,9	Slightly Negative during construction	None	Slight		None		None	None
Effect on Local Wildlife Breeding Habitat	1,6,8,9	Slight	None	None		None		None	None
Rare or Endangered Species Affected	5,8	None	None	None		None		None	None
Loss of Recreation Park	1,6,8,9	Yes, but would be mitigated	None	None		None		None	None
Historical and/or Archeological Sites affected through Riverbank Erosion	3,4	Negative during a flood	None	None		None		None	None
Effect on Stream Erosion	1,6	Negative during construction and flood	None	None		None		None	None
Mineral Resources Affected	1,6,8,9	None except material needed for project	None	None		None		None	None
Increased Flood Risk Upstream	2,3,6,8,9	Yes	None	None		None		None	None
Riverbank Vegetation Lost	1,6,9	1500 L.F.	None	None		None		None	None
Wildlife Habitat Lost (acres)	1,6,8,9	8	None	None		None		None	None
Wildlife Habitat Gained (acres)	2,6,8,9	4.4	None	None		None		None	None
3. Social Well-Being									
Developable Vacant Industrial Land	2,3,6,8,9	20 acres	Negligible	None		None		None	None
Industries Protected	1,6,8,9	4	None	3		None		None	None

TABLE 2-17
SYSTEM OF ACCOUNTS

Accounts	Footnotes (See Text "System of Accounts)	PLAN A BERKELEY LOCAL PROTECTION PROJECT LOCATION OF IMPACTS		PLAN B BERKELEY NONSTRUCTURAL PLAN LOCATION OF IMPACTS		WITHOUT CO[illegible] LOCATION OF	
		Within the Watershed	Within the Rest of the Nation	Within the Watershed	Within the Rest of the Nation	Within the Watershed	With of
Municipal Treatment Facilities Protected	1,6,8,9	1	None	None	None	None	
Trunk Sewer Line Protected	1,6,8,9	Yes (within project limits)	None	None	None	None	
Effect on Upstream Flooding	2,3,6,8,9	Slight to moderate	None	None	None	None	
Bridge Modifications, Removal	1,6,8,9	None	None	None	None	None	
Effect on Public Health, Safety	2,3,6,8,9	Slight during construction	None	Slight during construction	None	None	
Protection of Water Supply Station	2,3,6,8,9	Yes	None	None	None	None	
Effect on Recreation Activities	2,3,6,8,9	Yes, Park taken for easement	None	None	None	None	
Length of Concrete Walls for Local Protection	1,6,8,9	1450 L.F.	None	1130 L.F.	None	None	
Length of Earth Dikes for Local Protection	1,6,8,9	3800 L.F.	None	None	None	None	
Effect on Community Growth	2,3,5,8,9	Positive	None	None	None	None	
Duration of Construction Activities	1,6,7,9	2 years	None	Less than 2 years	None	None	
4. Regional Development							
Income							
Increases in the Area as Unemployed or Underemployed rejoin the Labor Force	1,6,7,9	Yes	None	Yes	None	None	
Expenditure Increases by Imported Construction Workers	1,6,7,9	Yes	None	Yes	None	None	
Employment							
Increases employment during plan implementation	1,6,7,9	Yes	None	Yes	None	None	
Increases employment in the long run	2,3,6,7,9	Yes		None	None	None	
Expands the labor force in the area	1,2,6,7,9	Yes, with new land development	None	None	None	None	
Desirable Community Growth							
Intensification of existing land use	2,3,6,7,9	Yes	None	Yes	None	None	
Contribute to *existing development* by reducing flood damages	2,3,6,7,9	Yes	None	Yes	None	None	
Reduce flood insurance premiums	2,3,6,9	Yes	None	Yes	None	None	
Removes restriction of Federally related financing for existing flood-prone properties	2,3,6,9	Yes	None	Yes	None	None	
Compatible with town-wide objectives for future land use	2,3,6,9	Yes	None	Yes	None	None	
Increases industrial activity	2,3,6,8,9	Yes, during construction	None	Yes, during construction	None	None	

TABLE 2-17
SYSTEM OF ACCOUNTS

Accounts	Footnotes (See Text "System of Accounts)	PLAN A BERKELEY LOCAL PROTECTION PROJECT LOCATION OF IMPACTS: Within the Watershed	PLAN A: Within the Rest of the Nation	PLAN B BERKELEY NONSTRUCTURAL PLAN LOCATION OF IMPACTS: Within the Watershed	PLAN B: Within the Rest of the Nation	WITHOUT CONDITIONS LOCATION OF IMPACTS: Within the Watershed	WITHOUT CONDITIONS: Within the Rest of the Nation
Taxes and Government Spending							
Increases business activity and tax revenues	2,3,6,9	Yes	None	Yes	None	None	None
Improves property values	2,3,6,9	Yes	None	Yes	None	None	None
Encourages municipal expenditures to improve community facilities	2,3,6,9	Yes	None	Yes	None	None	None
Transportation							
Increased heavy truck traffic	1,6,7,9	Yes, during construction	None	Yes, during construction	None	None	None
Protection of railroad tracks	2,3,6,7,9	Yes (within project limits)	None	Yes	None	None	None

Within the Rest of the Nation - In the study, this refers to the remainder of the Nation outside the Providence-Pawtucket-Warwick SMSA, and the immediate planning area. This area is used as an account balancing area.

Components of Accounts - The Principles and Standards (P&S) specify components of accounts which were considered in filling out the System of Accounts. Only components which significantly benefit from a project are displayed. Subcategorization of the components displayed is used to further specify the source and nature of the contribution.

National Economic Development (NED) - The NED account shows increases in the Nation's productive output, an output which is partly reflected in a national product and income accounting framework designed to measure the continuing flow of goods and services into direct consumption or investment. This account is filled out in dollar terms. Benefits and associated costs are expressed as average annual equivalent basis using appropriate periods of analysis and the prevailing discount rate. June 1981 price levels are used for this display item.

Environmental Quality (EQ) - The environmental objective is achieved by the management, conservation, preservation, creation, restoration or improvement of the quality of certain natural and cultural resources and ecological systems. This objective reflects society's concern that the natural environment be maintained and enhanced as a source of present enjoyment and a heritage for future generations. This account, along with the two accounts immediately following, have footnotes that depict specific impacts.

Social Well-Being (SWB) - This account includes most of the benef ts traditionally termed intangible under existing practice. Impacts and social well-being are best described in terms of effects on health, safety, community well-being, educational, cultural, and recreational opportunities.

Regional Development (RD) - This acount includes impacts of the proposed plan upon the impacted area in terms of resources displaced or better used in the event that the plan is implemented. Other components are the number and types of jobs gained or lost due to the action, the effects the action has on distribution of population and the losses or gains in output resulting from external diseconomics within the relevant regions. If a direct monetary economic benefit or loss is attributable to the action, it is included under the heading National Economic Development.

Nomenclature - Footnotes used in Table 2-17 for the System of Accounts analysis are as follows:

CODE	MEANING
	General
YES	Effect occurs in region shown
NO	Effect does not occur in the region
NA	Effect is not applicable to the region
NQ	Effect has not been quantified
NE	Effect has not been evaluated
*	Effect is specifically designated in Section 122 of Public Law 91-611 as one which must be identified and evaluated
	Timing of Impact
1	Designates that the impact is expected to occur prior to or during plan implementation
2	Designates that the impact is estimated to occur in 15 years or less after implementation of the plan
3	Designates that the impact is estimated to occur later than 15 years after the implementation of the plan
	Uncertainty
4	Designates that the level of uncertainty associated with an impact is greater than 50 percent
5	Designates an uncertainty range of 10-50 percent
6	Designates an uncertainty range of 0-10 percent, thus suggesting that the impact is virtually certain
	Double Classification
7	Designates that the SWB, EQ, or RD account item analyzed has been fully monetized and counted as an NED beneficial or adverse contribution
8	Designates that the SWB, EQ, or RD account item analyzed has been partially monetized
	Actual or Potential Effect
9	Designates that the contribution would likely occur without any action by any entity other than the proposed implementing agency, or the required action is extremely likely to occur through the economic or natural physical systems
10	Designates that the achievement of the beneficial contribution requires positive Governmental action by another agency, other than cost sharing. The adverse contribution associated with this action would likely be prevented by Government action
11	Used when coordination indicates that the action required by other agencies would not be forthcoming.

COMPARISON OF DETAILED PLANS

Comparison of Plans - Only the Berkeley LPP plans were found to be economically, technically, environmentally and socially feasible. Table 2-17 is a matrix showing quantitative and qualitative assessments of the impacts of the flood protection plans versus the without condition on the NED, EQ, SWB and RD factors. The baseline condition for EQ, SWB and RD assessments is the present degree of development in the study area.

The National Economic Development (NED) portion of Table 2-17 was determined by in-depth engineering and economic studies. The development of benefits and costs for the Berkeley Local Protection Plans are detailed in Appendix 7. All costs and benefits for the plans are based on the interest rate of 7-3/8 percent and June 1981 price levels.

Based on the NED factor, the Berkeley structural Plan A with a 100 year life provides a benefit/cost ratio of 1.35 and protects the plants which are vulnerable to flooding along the Blackstone River in the community of Cumberland, Rhode Island. A planning objective of the study is to provide the greatest possible degree of protection to the largest area. The Engineering Circular 1105-2-47, "Flood Damage Reduction Policy: Level of Protection," specifies that protection in urban areas be afforded up to a standard project flood level as long as it is economically justified. The non-structural Plan B provides 100 year level protection with BCR's ranging from 1.0 to 4.0 based on a 20 year life.

The impacts on environmental quality are indicated in part 2 of Table 2-17, System of Accounts, between the plans of protection and without condition. In "Environmental Impacts" the adverse effects are either major or minor.

Major - No significant impacts to man's environment should result from the construction of either Plan A or B. Plan A borrow operations might have a significant impact, but until a borrow site is located this cannot be determined.

Minor - A minor impact for Plan A would result from the elimination of approximately 11 acres of plant and animal habitat by the dike and the wall. Also, about 2.5 acres of habitat adjacent to the wall and dike will be temporarily disrupted because of the construction activities. Turbidity will increase in the Blackstone River due to erosion from exposed land and from filling operations. This problem can be substantially reduced, however, by proper planting of exposed areas and by proper construction practices. The beneficial impacts are also included in these reports.

With proper planting of the interior portion of the dike, approximately 2.2 acres of prime small animal habitat could be created. The quality of the habitat would exceed the present conditions and an increase

in animal population would likely occur. In addition, the dike and wall would protect nesting and forage areas of the resident population of animals.

Social Well-Being impacts are designated in Section 3 of Table 2-17. Four industries, a municipal pumping station and the Berkeley Oval ball-field would be protected by Plan A. The effect on downstream flooding would be slight, while the effect on public health and safety would be slightly negative only during construction. Plan B would provide protection to three industries and the pump station.

In regard to the Regional Development Account the structural plan for Berkeley LPP would have positive impacts. The effects are indicated in Table 2-17. Construction activities for Plan A would produce many new jobs and increase spending in the area. The industrial and commercial establishments along the river would be afforded a high, if not complete degree of protection against flooding and that could induce them to expand their operations. As they expand, more permanent type jobs would be created. All of the anticipated land growth or urban factors would conform with the proposed land use and zoning criteria currently established by the impacted municipalities.

PLAN SELECTION

On 16 June 1981, the Corps met with the Mayor of Cumberland, the Town Council and representatives of the three industries to review the structural Plan A and a cost effective Nonstructural Plan B to determine the support of each plan. Attending the two meetings on 16 June were:

Berkeley Industries and Mayor at 2 p.m. - 4 p.m. at Roger William's Plant

Len Furtado, Staff Assistant, Congressman St. Germain's Office
Francis R. Stetkiewicz, Mayor, Town of Cumberland
Scott B. Laurans, Treasurer-Exec. Vice President, Roger Williams Foods
(Plant Engineer also attended)
R.L. Gilson, National Distribution Manager, Health-Tex Inc.
Dick Chretien, Plant Engineer, Health-Tex Inc.
A.F. Angelone, Plant Manager, The Okonite CO.
Al Ereio, Tax Assessor, Cumberland
Arthur Doyle, Section Chief, Comprehensive River Basin Section, Corps
Robert Hunt, Acting Project Manager, Corps

Town Council, Cumberland 7 p.m. - 8:30 p.m. at the Town Hall

Mayor Stetkiewicz
Daniel J. Alves, Town Councilman, District No. 1
Tony Sauser I, Town Councilman, District No. 2
Michael A. Kelley (Attorney), Town Councilman, District No. 3 (Berkeley)
L. Richard Savage, Town Councilman, District No. 4
A. Doyle and R. Hunt

A comparison of the plans similar to Table 2-18 was provided along with displays similar to plates 3 and 5 in the Main Report.

The more significant differences between the two plans are shown on the table. Plan A meets the planning objectives to provide Standard Project Flood (SPF) protection to the industries, employees and other facilities in the Berkeley Industrial Park over a 100 year period. The SPF level of protection exceeds the level of the 1955 record flood by three feet. Plan B, although not providing SPF protection, does provide protection against a reoccurence of the flood of record. Employees, however, would need to evacuate the area until flood waters recede.

The first cost of Plan A is considerably higher than Plan B, although both have positive Benefit-to-Cost ratios, thus both are economically justified. Plan B with its higher BCR demonstrates higher economic efficiency with higher benefits per dollar of annual cost.

Two significant problems associated with Plan A are the potential adverse impacts on the Historic Blackstone Canal and on the Owens-Corning Fiberglas plant in Ashton. Preliminary indications are that the dike would restrict the cross-section of the river and increase the velocity of the river. This could possibly cause additional erosion along the already eroding tow-path dike of the canal. Detailed investigations would need to be accomplished during Advanced Engineering and Design to determine if a signficant impact would exist.

The dike as designed in Plan A would cause flood stages upstream in Ashton to be about 0.7 feet higher for 100 year frequency flood and 1.7 feet for a SPF event. Several alternatives were being considered to reduce this impact on Owens-Corning such as outright compensation, raising the plant's existing level of nonstructural protection or chosing nothing. Support for Plan A under Legislated Cost Sharing was previously provided by letter from the Town; however, another meeting was scheduled for 1 July 81 to determine support for Plan B following the resolution of a number of questions.

The major questions dealt with the feasibility of implementing plans under the cost sharing options. Implementation of Plan A would require from 7 to 10 years if approved and funded by Congress. The traditional or legislated cost sharing required local interests to pay lands, damages, utilities and relocations, and annual operation, maintenance and interim replacement costs. However, the former administration had proposed a policy where non-Federal interests pay a larger share than traditionally. As well as the traditional annual costs, the State would pay 5-percent and local interest 20-percent of the first cost.

TABLE 2-18

COMPARISON OF SIGNIFICANT DIFFERENCES
BETWEEN FINAL ALTERNATIVE PLANS

BERKELEY LOCAL PROTECTION
(June 1981 Price Level)

	PLAN A	PLAN B
1. Description:	SPF Structural Plan	100-year Nonstructural
2. Level of Protection:	SPF: Average 3-feet above 100-year or 1955 flood level	100-year: Approx. 1955 flood level
3. Project First Cost:	$6,142,000	$1,216,900
4. Benefit-to-Cost Ratio:	1.4 to 1	2.5 to 1 (Average)
5. Town of Lincoln's Historic Canal:	Minor Impact for 100-year event	No Impact
6. Increase flood stage at Owens-Corning Fiberglass:	100-year by 0.7 feet SPF by 1.7 feet	None None
Ave. Annual Loss Increase:	$100,000 (Approx.)	None
7. Plan Support:	Federal/State/Local support; Town of Lincoln's Conser. Comm. opposed.	Town and local industry support, July 1981.
8. Implementation Process:	• Complete feasibility report • Extensive report review • Congressional Authorization • Congressional Funding • Local Assurances & Funding	• Detailed Planning • Limited report review • Corps' Sec. 205 Author. and Funding Section 73 • Local Assurances & Funding
9. Project Completed:	7-10 years, if authorized by Congress	3-4 years, if approved by Corps
10. Cost Sharing		
(1) Legislated: Federal First Cost:	$5,916,000	$973,500 (80%)
Non-Federal First Cost:	$ 226,000	$243,400 (20%)
Incl. 168k, land & damages 58k, roads/utilities relocation		Incl. $59,400 L&D
Non-Federal O&M & Replace:	$ 16,700/year	$ 1,100/year
(2) President's Policy:		
Federal First Cost:	$4,606,500 (75%)	n/a
Non-Federal First Cost:	$1,535,500 (25%)	n/a
Non-Federal O&M, & Replace:	$ 16,700/year	n/a

Plan B, however, could be implemented in 3-4 years under the Corps' small project authority. Cost sharing under Section 73 of Public Law 92-251, would require local interests pay annual costs plus 20-percent of first costs.

The major questions were whether any projects had been funded under these cost sharing options, and what was the feasibility of each plan being implemented. The industries also wanted to determine their annual insurance savings under each plan prior to plan selection.

At the 1 July 1981 meeting the Questions and Answers in Table 2-19 were provided the Mayor, Town Council and industry representatives. Attending the meeting on 1 July were:

<u>Roger Williams Plant, Berkeley</u>

Mayor Francis R. Steckiewicz, Town of Cumberland
Michael A. Kelley (Attorney), Town Councilman, Dist. #3 (Berkeley)
L. Richard Savage, Town Councilman, Dist. #4
Al Ereio, Tax Assessor, Cumberland
R.L. Gilson, National Distribution Manager, Health-Tex Inc.
Scott B. Laurans, Treasurer-Exec. Vice President, Roger Williams Foods
Arthur Doyle, Ch., Comp. River Basin Sec., Corps
Robert Hunt, Acting Project Manager, Corps

Questions Q1 to Q4 received very little discussion due to the Answers in Q5 to Q9. It was apparent from the later answers that their was very little chance that Plan A would be approved by Congress under the traditional or Legislated Cost Sharing, since indications were that the current administration was formulating cost sharing policies similar to the former administration's. Since the Non-Federal Cost of Plan A at 25 percent exceeded the Town's resources, representatives at the meeting generally concluded that only Plan B currently appeared implementable and would be better than no plan. The industry representatives who were present at the meeting (Roger Williams and Health-Tex) both indicated they could help finance Plan B from flood insurance savings.

Plan B was selected for implementation under the Corps' Continuing Authority (see 31 July 81 letter from the town of Cumberland in Main Report).

1 July 1981

TABLE 2-19

BERKELEY LOCAL PROTECTION

QUESTIONS AND ANSWERS

(Following 16 June 1981 Meeting)

Q-1 WHAT IS PLAN A's DIKE EFFECT ON THE RIVER?

A-1 From Martin Street Bridge to the upstream end of the proposed dike, there would be no significant change in river velocity; although for a 100-year frequency flood event the stage of flooding would average 1.7 feet higher with the dike than without it.

From Martin Street Bridge to the downstream end of the proposed dike, there would be about a 30 percent increase in river velocity for a 100-year event with only a slight increase in river stage.

Q-2 WILL THERE BE AN IMPACT ON THE CANAL?

A-2 The Corps would need to determine the current stability of the canal's tow path dike and its susceptibility to erosion with and without Plan A to determine if an impact is significant. This would be accomplished during the Advanced Engineering and Design Phase. If the impact is significant, solutions to mitigate the impact will be discussed and appropriate costs would be included in the project cost for the accepted solution.

Q-3 WHAT IS PLAN A's IMPACT IN ASHTON?

A-3 Plan A would raise the river stage in Ashton about 0.7 feet for the 100-year flood event and 1.7 feet for a Standard Project Flood (SPF) event. This impact would increase flood stages at both a residence in Lincoln adjacent to the Washington Bridge and at the Owens-Corning Fiberglas Plant on the river.

Q-4 WHAT MEASURES CAN BE TAKEN TO REDUCE IMPACTS?

A-4a The resident could be considered for relocation or the building flood proofed. The measures would be evaluated during AE&D and if feasible this cost would be included with the project cost, and in cost sharing for Plan A.

A-4b Several options are being considered to reduce possible impacts at Owens-Corning: nonstructural flood proofing, structural flood protection, change in Berkeley project design, compensation for damages, relocation of Fiberglas or do nothing.

Q-5 HAS THE CONGRESS AUTHORIZED AND FUNDED ANY FLOOD CONTROL PROJECTS UNDER EITHER COST SHARING, TRADITIONAL/LEGISLATED OR THE PRESIDENT'S POLICY, SINCE THE PRESIDENT'S POLICY WAS ESTABLISHED?

A-5 No.

Q-6 WHAT ARE THE CHANCES OF PLAN A BEING IMPLEMENTED UNDER THE LEGISLATED COST SHARING?

A-6 The current administration is presently preparing their cost sharing policy. Indications are that their policy will more closely resemble the former administration policy (75 percent Federal/25 percent non-Federal) rather than the legislated with non-Federal interests only paying lands, damages and relocations). Approval of Plan A with traditional cost sharing is very unlikely.

Q-7 CAN THE CORPS RECOMMEND PLAN A WITH TRADITIONAL COST SHARING?

A-7 No, the Corps can only recommend Plan A under the President's Policy, however, we could note that locals only support the plan under traditional cost sharing.

Q-8 HAS THE CORPS EVER AUTHORIZED A NONSTRUCTURAL PLAN UNDER THE SECTION 205 AUTHORITY?

A-8 Yes, several projects have recently been authorized under Section 205 with funding under Section 73 (P.L. 93-251) the Water Resources Development Act of 1974 ie. Warwick, Rhode Island (design underway), California (approved by Washington).

Q-9 HOW WOULD PLAN B, NONSTRUCTURAL BE IMPLEMENTED?

A-9 The Corps would immediately turn Plan B over to our Small Project Section for completion of a Detailed Project Report (DPR). After Corps approval plans and specs would be prepared and construction funded.

PAWCATUCK RIVER AND NARRAGANSETT BAY

DRAINAGE BASINS

WATER AND RELATED LAND RESOURCES STUDY

FEASIBILITY STUDY

BLACKSTONE RIVER BASIN

RHODE ISLAND AND MASSACHUSETTS

APPENDIX 3

PUBLIC VIEWS AND RESPONSES

PAWCATUCK RIVER AND NARRAGANSETT BAY
DRAINAGE BASINS
WATER AND RELATED LAND RESOURCES STUDY

FEASIBILITY STUDY
BLACKSTONE RIVER BASIN
RHODE ISLAND AND MASSACHUSETTS

APPENDIX 3

PUBLIC VIEWS AND RESPONSES

PREFACE

This appendix includes pertinent Congressional, Federal, State and local correspondence regarding support and concerns for implementing the flood management plan. These concerns were based on preliminary findings reported in advance of study completion. Comments from those on the inclosed list reviewing the draft report will be included in the final appendix. Appropriate changes or additions have been made to the report.

PAWCATUCK RIVER AND NARRAGANSETT BAY
DRAINAGE BASINS
WATER AND RELATED LAND RESOURCES STUDY

FEASIBILITY STUDY
BLACKSTONE RIVER BASIN
RHODE ISLAND AND MASSACHUSETTS

APPENDIX 3

PUBLIC VIEWS AND RESPONSES

TABLE OF CONTENTS

DESCRIPTION OF PUBLIC INVOLVEMENT PROGRAM

In keeping with the policy of the Chief of Engineers to conduct his Civil Works program in an atmosphere of public understanding, trust, and mutual cooperation, all interested individuals and agencies were informed and afforded an opportunity to be fully heard and their views considered in arriving at conclusions, decisions, and recommendations in the formulation of civil works proposals, plans, and projects and on the proposed uses of navigable waters. Formally organized and announced public meetings provide one important means of accomplishing this objective. Other desirable public participation and information measures such as workshops and close coordination between towns and individuals also contributed to this objective.

Formality is intended only in respect to organization and announcement. The atmosphere of the meetings were informal to the extent practicable, in keeping with the concept of public involvement and the need to encourage and develop more meaningful, two-way communication.

The primary purpose of the public meetings was to help insure that solutions to flooding problems satisfy the needs and preferences of the people to the maximum degree possible within the bounds of local, State, and Federal interests, responsibilities, and authorities. More specifically, the purposes of the public meetings were to inform the public about studies and proposals related to flooding and to give all interested persons an opportunity to fully and publicly express their views concerning such studies and proposals; to obtain and exchange information which will assist all those involved in arriving at sound conclusions and recommendations; and to contribute to interagency coordination.

An initial meeting was held early in the course of the study, in May 1969, to define the nature and scope of the study, to open lines of communication, to listen to the needs and views of the public, and to identify interested individuals and agencies.

Throughout the study, close contact was continued with Congressman St. Germain's office, the Pawtucket-Blackstone Valley Chamber of Commerce, the Blackstone Valley Council of Government, the State of Rhode Island Historical Preservation Committee, the Pawtucket-Blackstone Valley Chamber of Commerce, the Governor's office, and the Committee for the Advancement of Natural Areas in Lincoln.

Although no action was taken at the time, the complaints and the suggestions were noted from the above groups and were considered when the study of the Berkeley area in Cumberland, Rhode Island was underway.

A late stage meeting was held in December 1978 after detailed studies but before report completion. Findings of the detailed studies, including the rationale for any proposed solution, and the tentative recommendations of the reporting officer were presented.

Correspondence was maintained after the 7 December 1978 public meeting with the towns of Lincoln, Central Falls, and Cumberland as well as the Rhode Island statewide planning program.

The towns of Lincoln and Cumberland have requested another meeting, but it has not yet been held because of the delay regarding the details of the President's cost formula.

Following are the summaries of the public meeting held in 1969 and in 1978 with correspondence regarding each meeting.

SUMMARY OF MAY 1969 PUBLIC MEETINGS

On initiation of the Pawcatuck River and Narragansett Bay Drainage Basins Study, in early calendar year 1969, four public hearings were held, one each in Taunton and Uxbridge, Massachusetts; Providence and Kingston, Rhode Island. The purpose of these hearings was to afford individual citizens, municipal and State officials, and other Federal agencies an opportunity to present their views and desires concerning the need and extent of improvements on flood reduction measures and other interrelated water-oriented resources.

To supplement information received at the public meetings, and to fully evaluate and update the inventory of flood problem locations and related water resource needs, letters requesting such information were mailed to responsible local officials. Concurrently numerous informal meetings with State agencies, the Pawtucket-Blackstone Valley Chamber of Commerce, and personal contacts with Federal agencies and individual citizens were initiated.

Since the initial hearings, additional requests for Federal assistance in solving specific flood problems have been received. Some of the requests have been considered under other existing authorities available to the Corps of Engineers, such as Section 205 of the Flood Control Act of 1948, as amended. Other requests received and processed came under the purview of the clearing and snagging authority as covered in Section 208 of the Flood Contol Act of 1954, as amended; Section 14 of the 1946 Flood Control Act involving emergency bank slope protection; and PL 99 consisting of restoration of existing works.

Substantial local support has been growing steadily within the Blackstone River watershed. The Pawtucket-Blackstone Valley Chamber of Commerce has expressed an interest, and has supported and been instrumental in the acceleration of the studies in this watershed.

That organization has offered encouragement and has disseminated information to local interests asking for their whole hearted support. This has resulted in meetings becoming more fruitful with indications of general support and genuine willingness to participate in the investigation of the watershed.

The General Manager of the Rhode Island Water Resources Board brought attention to the State water supply plans which, through development of new surface reservoirs and ground water supplies, would provide the State with an adequate supply for all purposes up to the year 2020. These plans were presented so that proper consideration would be given in light of the flood control studies.

Other requests for improvements desired included channel modification involving various methods of restoration work such as:

a. Possible elimination of abrupt turns and oxbows.

b. Widening, deepening and channel realignment of certain stretches of river.

c. Improvement of waterway areas at bridges, culverts and at other constriction points.

d. Selective planting and/or revetment works for alleviating erosion problems.

e. Removal of shoals, sandbars, and piles impeding minor floodflows.

f. Removal of vegetation, overhanging trees, shrubs, and accumulated silt and debris at critical points.

CORRESPONDENCE PRIOR TO THE
7 DECEMBER 1978 PUBLIC MEETING

Letters From:

Congressman Fernand St. Germain - 5 August 1970

Congressman Fernand St. Germain - 19 March 1971

Pawtucket-Blackstone Valley Chamber of Commerce - 19 October 1971

Pawtucket-Blackstone Valley Chamber of Commerce - 10 March 1972

Blackstone Valley Council of Governments - 2 April 1974

Blackstone Valley Council of Governments - 12 December 1974

State of Rhode Island, Historical Preservation Commission - 2 February 1977

State of Rhode Island, Historical Preservation Commission - 5 April 1977

Congressman Fernand St. Germain - 12 July 1977

US Department of Interior, Fish & Wildlife Service - 22 September 1977

State of Rhode Island, Governor - 17 November 1978

State of Rhode Island, Governor - 20 November 1978

Congressman Fernand St. Germain - 20 November 1978

State of Rhode Island Historical Preservation Commission - 21 November 1978

Committee for the Advancement of Natural Areas in Lincoln - 1 December 1978

US Department of Agriculture, Forest Service - 4 December 1978

FERNAND J. ST GERMAIN
1ST DISTRICT, RHODE ISLAND

1201 LONGWORTH HOUSE OFFICE BLDG.
WASHINGTON, D.C. 20515

200 CUSTOM HOUSE
PROVIDENCE, R.I. 02903
TEL.: 272-7330

COMMITTEES
BANKING AND CURRENCY
GOVERNMENT OPERATIONS

Congress of the United States
House of Representatives
Washington, D.C. 20515

August [illegible], 1970

Lt. Gen. F. J. Clarke
Chief of Engineers
Department of the Army
Washington, D.C. 20310

Dear General Clarke:

At the end of July the Blackstone River, Woonsocket, Rhode Island, washed out Woonsocket's trunk sanitary sewer crossing the river, rendering it useless, and polluting the river because of the continuous flood of sewage. I immediately contacted Col. Frank P. Bane, New England Division, Corps of Engineers, Waltham, Massachusetts, and with his cooperation arranged a meeting that was attended by Mayor [illegible] Lussier, Mr. Robert [illegible], Director of Public Works, Mr. Edwin Coffin, and Mr. Charles Sullivan. This meeting was held on Monday, August 3.

With the completion of the two existing flood control projects in the upper and lower reaches of the Blackstone River, it is now concluded that there is a definite need for protective work along both banks of the river in the area between the two projects.

The river has eaten away much of the island that existed in the old Bernon Pond. With the continuous erosion of the east bank, the river now flows dangerously close to the rear of the homes facing Front Street in Woonsocket. This condition is cause of great concern.

When Bernon Pond was eliminated, the above mentioned island disappeared. With the [illegible] of the Green [illegible] program the city grasped an opportunity to fill in the [illegible] channel to create a recreational area by the river's side. Such an area would have been a source of pride for the whole community. Unfortunately, the high water of March [illegible] cut through the old channel and recreated the island.

Frankly, there is a very serious question in my mind as to whether or not the rupture of the sewer line was caused by the flood control work on the upper and lower reaches.

When the last phase of flood control was being designed, it is my understanding that the area now in question was found ineligible because it did not meet the cost-benefit ratio requirements.

Since that time, however, many events and changes have taken place. There have been problems with a sub-station of the electric company, and several industrial plants have been affected. New emphasis, furthermore is being placed upon other factors being considered, such as the Green Acres Program, ecology, and naturally, prevention of pollution. In addition, the Master Plan provides for the erection of recreational facilities in a reclaimed area behind the Island Place section of the Blackstone River between South Main Street and Vernon Street.

Therefore, I am requesting that a preliminary study be made of the Blackstone River channel between the limits of the upper and lower flood protection projects. I would ask that this study be made with a view to determining whether it would qualify for immediate action under the Small Projects Category (those costing under $1 million).

A speedy reply and, hopefully, study is called for, since the expenditure to repair the sewer line will be in the area of $150 to $200 thousand. Certainly you can appreciate the importance to the City of Woonsocket of knowing whether this flood work can be done prior to finalizing plans for the sewer line.

Yours sincerely,

F. St Germain

Fernand J. St Germain
Member of Congress

FJStG/jb

...ICT, RHODE ISLAND

...BURN HOUSE OFFICE BLDG.
WASHINGTON, D.C. 20515

JOHN E. FOGARTY BUILDING
PROVIDENCE, R.I. 02903
TEL: 528-4323

BANKING AND CURRENCY
GOVERNMENT OPERATIONS

Congress of the United States
House of Representatives
Washington, D.C. 20515

March 19th, 1971

Col. Frank P. Bane
New England Division Engineer
Department of the Army
Waltham, Massachusetts

Dear Colonel Bane:

I discussed this preliminary brief with members of your staff. Mr. Don Martin asked that I forward it for evaluation so that you might recommend to me which route should be followed to further help this regional flood control project.

Your comments and advice would be deeply appreciated by all the individuals and businesses affected.

Yours sincerely,

Fernand J. St Germain
Member of Congress

FJStG/jg
Enclosures

A BRIEF SUPPORTING AN APPLICATION FOR A

BLACKSTONE RIVER FLOOD CONTROL PROJECT

TO

THE HONORABLE FRANK LICHT
GOVERNOR, STATE OF RHODE ISLAND

THE HONORABLE JOHN O. PASTORE
UNITED STATES SENATOR

THE HONORABLE CLAIBORNE PELL
UNITED STATES SENATOR

THE HONORABLE FERNAND J. ST. GERMAIN
UNITED STATES REPRESENTATIVE
FIRST CONGRESSIONAL DISTRICT

THE HONORABLE ROBERT O. TIERNAN
UNITED STATES REPRESENTATIVE
SECOND CONGRESSIONAL DISTRICT

FROM:

Robert F. Burns, Mayor	City of Pawtucket
Roland E. Messier, Mayor	City of Central Falls
Edward J. Hayden, Town Adm.	Town of Cumberland
Barry J. Farrands, Town Adm.	Town of Lincoln
	Pawtucket-Blackstone Valley Chamber of Commerce

he following parties of record:

Company	Approx. Employment	Plant Area Sq. Ft.
Owens-Corning Fiberglas Corp.	500	325,000
Ann & Hope (Cumberland)	600	750,000
Cadillac Textiles Incorporated	280	200,000
Lonsdale Pharmacy Inc.	14	7,500
Collins Bros. Machine Co.	35	20,000 (that flood affect:
Roger Williams Grocery Company	130	140,000
U. S. Philips Corp. - Cryogenic Div.	129	39,000
Central Beverage Corporation	25	15,000
International Packaging Corp.	350	125,000
Grace Holmes, Inc.	300	250,000
Carol Cable Company	500	250,000
Standard Romper Co., Inc. (Cumb.)	130	120,000
LaBrie Shoe Stores	8	7,500
Darlton Wood Works Corp.	18	20,000
Lonsdale Twin Drive-In Theatre	30	20 acres
Puritan Aerosol Corporation	450	210,000
lizabeth Webbing Mills	400	300,000
Cowl ~~Ansonia~~ Wire & Cable Co.	200	120,000
Old Slater Mill Association		

And others.

We, the signatories, on behalf of our respective communities, nd on behalf of the list of business firms attached hereto, respectfully petition the State of Rhode Island and government of the United States to establish a specific project for remedies from flooding on the lower Blackstone River.

Schedule A, attached, is a brief description of the floods of the past 40 years, and of the damages that occurred.

This concern about the damage from flooding has been intensified by the recent completion of a 42" trunk line sewer along the Blackstone River to the Woonsocket city line. The probability of the destruction of this sewer line in a repetition of the 1938 or 1955 floods is quite real. One section of the Providence & Worcester Railroad, beside which the sewer line is laid, was completely washed away in 1955.

1970, contact was made with the U. S. Army Corps of Engineers office in Waltham, Massachusetts. It was learned that the Blackstone River is included in a general flood study of the Narragansett Bay drainage areas, but a reduction in appropriation from $400,000 to $70,000 was made by the Congress with respect of the Blackstone River phase of this study. As a result, all that can be expected will be a flood plains report, with no study or recommendations for protection of relief. An inquiry of the New England River Basins Commission brought a response that the Commission was aware of the problems, but that the primary responsibility belongs to the Corps of Engineers.

AD-A120 064 CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV F/G 13/2
PAWCATUCK RIVER AND NARRAGANSETT BAY DRAINAGE BASINS. WATER AND--ETC(U)
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In addition to the great economic losses at times of flooding, other serious concerns include the damage and pollution of municipal water supply wells along the river; the damage to the Blackstone Canal (recently declared a National Historic Site) which is valuable historic and recreational resource.

FLOOD SITUATION

Main Flood Season

The main flood season for the Blackstone River may be expected to occur during any season of the year. Early spring rains combined with melting snow resulting in the floods of March 1936 and 1968. Heavy rains during summer and fall months caused the floods of November 1927, July 1938, September 1954, October 1955 and the record flood of August 1955. The following paragraphs briefly describe the more important storms which have occurred in the past.

***

The Greatest Flood

The greatest flood on the Blackstone River, according to available records, occurred in August 1955. The flood resulting from the "Hurricane Diane" storm on the Blackstone River and its principal tributaries was approximately twice the magnitude of any flood of record. Several days prior to the occurrence of the flood, "Hurricane Connie" deposited nearly five inches of rainfall on the

basin which saturated the ground and filled the many lakes and mill ponds. However, the runoff associated with this storm failed to cause any significant rise in the rivers.

During the afternoon of 17 August '55 rainfall accompanying "Hurricane Diane" began and increased in intensity to such a degree that accumulations in excess of five inches were recorded by nightfall of the 18th. Heavy rainfall continued throughout the evening of the 19th until the storm finally moved out to sea, leaving an average of twelve inches over the basin with total accumulations ranging from eight to fifteen inches.

A few newspaper excerpts of this flood are as follows...

...Blackstone River reached its highest flood stage in history, the river rose 3½ inches per hour (between 12:45 a.m. to 1:45 a.m.)...

...In Central Falls, residents between the Blackstone River and High Streets were alerted to evacuate...

...Lonsdale Sports Arena was filled with water...

...North of John Street a Drive-in Theater being built was filled with water...

...All buildings on the river side of Roosevelt Avenue to the old police station reported flooding...

...Water ran over the retaining wall just south of the Exchange Street bridge and flooded the Municipal building area...

...Slater Mill threatened...water filled the basement and covered the first floor...

Other Great Floods

Other great floods of nearly equal magnitude occurred in March 1936, July 1938, and most recently in March 1968. These floods are considered the second highest floods on the Blackstone River. The magnitude of the March 1968 flood was actually about 10 per cent greater than the 1936 and 1938 floods, however the flood discharges were reduced to about the 1936 and 1938 flood levels by the West Hill flood control dam.

March 1936

The March 1936 flood actually occurred as two peaks of almost equal magnitude six days apart. The first peak, slightly less than the second, was the result of a combination of rainfall which varied from 3 inches in the lower part of the basin to 7 inches in the upper part. In addition, the already saturated soil reduced the rate of infiltration and, therefore, contributed in producing run off coefficients as high as 90 percent.

The following are excerpts from newspapers concerning the March 1936 flood in the study area:

...Homes were evacuated in Central Falls on Courtland Street and Notre Dame Plat..

...Masurel Worsted Company, Samoset Mills, and Nyanza Mills closed...water was 7 feet deep around the Masurel plant...

...John Plush Mills had 5 feet of water on grounds...

...In Lincoln and Cumberland, the Blackstone overflowed its banks...Mendon Road from Broad Street, Cumberland to John Street,

Lincoln was closed with water 1 foot deep in highway...

...Between Whipple bridge and grade crossing of NY, NH, & H Railroad in Lonsdale a distance of 500 years of State Highway 122 was flooded...

...Lowlands south of Whipple Bridge and John Street was completely flooded. Early yesterday morning John Street baseball field was like a Mill Pond...

March 1968

During this storm a total of 4.96 inches of rainfall was recorded at Hillsgrove U. S. Weather Bureau station. The storm spanned a three day period from March 17 to March 19. Snow depths and water equivalents in New England were nearly normal. Most of the water thus contained was released due to the rain and accompanying thawing temperatures during the storm. Frozen ground surfaces during most of the storm meant very little water was able to percolate into the ground. Most of the rain and snowmelt, therefore, was converted into runoff, flooding basements along the way, causing rapid rises on small ponds, brooks, and streams and finally... more slowly but quite predictably...near record crests on the Blackstone River.

Some newspaper excerpts are as follows:

...The Pawtucket Water Department faced an emergency as water from the Blackstone River flooded its water purification plant in Cumberland...

...The Sayles Finishing Plant Complex off Walker Street in Lincoln was hard hit...

...The warehouse of Roger Williams Grocery Co. off Mountain Street in Cumberland was surrounded by 6 feet of water...

...Several small industries and the large Lonsdale Bleachery Complex were inundated by flood waters...

...Mendon Road in Cumberland from the Lincoln town line to Broad Street was closed after it became inundated...

...Flood conditions forced closing of the westbound lanes of the George Washington Highway from the Cumberland line to the H & H Screw Co. in Lincoln...Also closed because of flooding was the Martin Street bridge in Cumberland...

...In Central Falls, cellars were flooded in 15 homes in Notre Dame Plat adjacent to the Blackstone River...

...In Pawtucket, The Blackstone River was 6.5 feet above normal and there was extensive damage in city streets...

Other Floods

Other floods of lesser magnitude since 1900 occurred in November 1927, September 1938, September 1954, and October 1955. Historical records indicate that floods occurred in 1818, 1876, 1877, 1886, and 1887, however, information on these events are meager in most cases.

***

New Threat Added

One of the most needed and useful environmental controls in the Blackstone Valley was completed in 1970 with the construction of a 42" trunk sewer line from Lonsdale to Woonsocket. Most of this pipeline was laid along the river banks and is almost entirely in the flood zone. The Waterman Engineering Co. contractors have taken extraordinary precautions to protect this line both from infiltration and breakage but if a flood greater than the 1968 flood should occur damage to the line is almost certain.

The main point is that under whatever circumstance the sewer line was broken a 42" open end injected with flood waters would completely flood the system with a definite possibility of considerable destruction at the main plant. It must be repeated that the contractors and engineers have done a most admirable job in preparing for known flood hazards in construction of this facility, but it is by no means a blanket guarantee that flood damage cannot occur and this would result in a disaster of immense proportions. Virtually, everything north of East Providence and east of Smithfield would be shut down--homes, businesses and industries.

SUMMARY OF FLOOD SITUATION

The Towns of Cumberland and Lincoln and the Cities of Central Falls and Pawtucket which comprise the study area are located in northern Rhode Island. This covers 10.6 miles of the Blackstone River from the Woonsocket-Cumberland town line downstream to the Old Slater Mill Dam in Pawtucket, Rhode Island.

Discharge information for the area are obtained by relating to the U. S. Geological Survey stream gaging station on the Blackstone River in Woonsocket, Rhode Island, which has been in operation since 1929. Whenever floods are expected to occur in the lower Blackstone River basin, these discharges are reduced (modified) by the U. S. Army Corps of Engineers flood control dam and reservoir (West Hill Dam) located on the West River in Uxbridge, Massachusetts. The flood control project which was built subsequent to the August 1955 flood of record has been in operation since 1961.

Most of the residential and business development in the study area are on high ground above flood danger from the Blackstone River. However, there remains residences and commercial and industrial developments along the river which have been inundated by floods of the past and remain susceptible to floods in the future.

The most recent flood in the Blackstone River basin occurred in March 1968. This storm produced near record crests on all major rivers in Southern New England.

The technical and advisory assistance of Fenton C. Keyes Associates in the preparation of this brief is gratefully acknowledged.

October 19, 1971

Chief
Office of Planning
U. S. Army Corps of Engineers (N.E.)
424 Trapelo Road
Waltham, MA 02154

Attention of Mr. Bergen

Dear Mr. Bergen:

First may I express my appreciation to you and Mr. Milette for your kind assistance and cooperation at our meeting on Thursday, October 7th. It was most helpful and informative.

The flood plain report has been received and brings me to my first request. Your cover letter indicates that additional copies of the flood plain report are available. We have some 56 active committees and at least 24 of these are directly or indirectly involved in Blackstone Valley developments. Without attempting to cover even our membership, I could easily distribute around 200 of the brochures to related groups concerned with water resources, development of land use plans, contractors, and engineers.

I have enclosed for your information a copy of my report which I gave to my Board of Directors today, and it was well received. I have spoken to the President of the Slater Mill Association, and I believe he is most amenable to the modification of the Slater Dam. What I am seeking now are [illegible] ement those informal discussions with representative groups that you indicated would be a necessary step in bringing about some positive results.

I am also ready to send the questionnaire out to the individual companies located in the study area, and

150 MAIN STREET, PAWTUCKET, R. I. 02860 TELEPHONE 401-722-3400

I am hoping that Mr. Milette might devise a question sheet that would contain all the right questions for the survey.

My Board would like to take action simultaneously on several fronts - i.e. doing the survey, holding the informal meetings and perhaps preparing an input to our Congressional delegation regarding a 1973 budget appropriation.

I would be grateful for your comments on my report to the Board. I tried to tell it like it was, and as I mentioned, it was received most favorably.

Would you let me know if I can get or order 24 copies of the report and about 200 of the brochures?

Thanks again for your help.

Yours truly,

George R. Bennett
Manager
Industrial Development Department

GRB:md
Enclosure

March 10, 1972

Colonel Frank P. Bane
Division Engineer
Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Colonel Bane:

Our most informative staff conversations with Mr. Millette and Mr. Bergen relating to the Blackstone Ri Flood Controls have now reached the point where Congressm St. Germain together with the Statewide Planning Board, the Rhode Island Water Resources and the Soil Conservation Service have requested the Chamber of Commerce to arrange for a presentation by the Army Corps of Engineers.

This presentation, covering the whole watershed area affecting the Blackstone, would be made by the Army Engineers to the Chief Executives of the communities involved i.e. Pawtucket, Central Falls, Lincoln, Cumberland, Woonsocket, Burrillville, Smithfield, North Smithfield, and North Providence.

The Board of Directors is therefore making this formal request to you to approve and authorize Mr. Millette and Mr. Bergen to make such a presentation to the above group on Friday at 4 p.m. at the TK Club in the City of Pawtucket. The presentation will be followed by a dinner where all will be guests of this Chamber.

Flood damages created by this last weeks rain has resulted in some headlines regarding flood controls and while our meeting will be entirely private and no press will cover, the matter of publicity will be an agenda item.

I would be most grateful if you can see your way clear to approve this request and our letters of invitation will be held up pending your reply.

PAWTUCKET BLACKSTONE VALLEY CHAMBER OF COMMERCE
150 MAIN STREET, PAWTUCKET, R. I. 02860 TELEPHONE 401-722-3400

Yours truly,

Robert N. Stoecker

Robert N. Stoecker
President

RNS:md

BLACKSTONE VALLEY COUNCIL OF GOVERNMENTS

150 MAIN STREET, PAWTUCKET, RHODE ISLAND 02860 TELEPHONE 401-723-7772

April 2, 1974

Mr. Leo R. Milette, P.E.
Project Engineer, Comprehensive River
Basin Section
Department of the Army Corps
of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Milette:

Enclosed is a copy of the statement of the Economic Development Policy of the Blackstone Valley Council as duly adopted by the Council of Governments on March 27, 1974 at its semi-annual meeting.

When I met with you in late December, you said that phase one of the flood control study of the Blackstone River was nearing completion and that the Council of Governments might receive a presentation of the same.

What is the status of the study?

If a presentation to local leaders would be appropriate, please contact me.

Very truly yours,

Kenneth F. Payne

Kenneth F. Payne
Assistant Director

KFP:af
Enclosure

BLACKSTONE VALLEY COUNCIL OF GOVERNMENTS

150 MAIN STREET, PAWTUCKET, RHODE ISLAND 02860 TELEPHONE 401-723-7772

December 12, 1974

Mr. Lawrence Bergen
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Mr. Bergen:

At its November 21, 1974, meeting, the Blackstone Valley Council of Governments adopted a resolution of support for the Army Corps of Engineers flood management plan for the Blackstone River Watershed as presented on November 1st at the Pawtucket-Blackstone Valley Chamber of Commerce.

The Blackstone Valley Council of Governments is a regional organization of seven Blackstone Valley municipalities: the cities of Pawtucket, Central Falls, and Woonsocket, and the towns of Cumberland, Lincoln, Smithfield, and North Smithfield.

This resolution of support by the Blackstone Valley Council of Governments is an indication of interest in and local support for the general proposal presented by the Corps.

Please keep me informed of any further developments in the Blackstone River Watershed flood control study.

Very truly yours,

Kenneth F. Payne
Executive Director

KFP:af

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

HISTORICAL PRESERVATION COMMISSION
Old State House
150 Benefit Street
Providence, R. I. 02903
(401) 277-2678

February 2, 1977

Mr. Joseph L. Ignazio, Chief
Planning Division
Army Corps of Engineers
New England Division
424 Trapelo Road
Waltham, Mass. 02154

RE: NEDPL-R-Berkeley
Industrial Park,
Cumberland, R.I.

Dear Mr. Ignazio:

We have reviewed the plans and specs for the above project as provided with your letter of 4 January, 1977.

The proposed work will have an effect, possibly adverse, on the adjacent Blackstone Canal Historic District, which is listed on the National Register of Historic Places. An exact determination of effect will require further study on our part, as well as additional information from the Corps.

The small maps and plans sent with your request for a determination were unfortunately illegible. We would like to receive clear, large scale maps and plans which show the following:

1. Precise location and extent of dikes, retaining walls and other structures;
2. Current allignment of river banks vs. proposed allignment;
3. Typical cross sections through the river, canal and portions of the proposed dikes and walls;
4. Relation of the canal to the river in the project area.

In addition, we would like to know what provisions are being made for preventing deterioration of the western bank of the Blackstone River and of the Blackstone Canal due to increased flow and water velocity as a result of this project.

Yours truly,

Frederick C. Williamson

Frederick C. Williamson
State Historic Preservation Officer

FCW/mm

cc: Jordan Tannenbaum

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

HISTORICAL PRESERVATION COMMISSION
Old State House
150 Benefit Street
Providence, R. I. 02903
(401) 277-2678

5 April 1977

Mr. Joseph L. Ignazio, Chief
Planning Division
Army Corps of Engineers
New England Division
424 Trapelo Road
Waltham, Mass. 02154

RE: NEDPL-R: Berkeley Industrial Park, Cumberland, R.I.

Dear Mr. Ignazio:

Thank you for the large scale plans and aerial photos of the Berkeley Industrial Park protection project provided with your letter of 17 February. They were a great help to our staff.

We have re-examined the project, and have concluded that the effect of the dike and other improvements upon the Blackstone Canal (entered on the *National Register of Historic Places*) will be twofold: visual and physical.

1. Visual effect: The eastern river bank improvements will have a visual effect on the Blackstone Canal, but the effect will be non-adverse due to sightlines, the fact that the towpath provides some screening between the canal and the eastern river bank, and the fact that the views from the canal are already compromised by the industrial park which the project is designed to protect. The dike and wall will in fact help screen the industrial park from view.

2. Physical effect: The alteration to the eastern river bank will probably have a physical effect on the canal, but the effect is impossible to evaluate without further information from the Army Corps. Although we have been assured verbally by your office that the increase in flow and height due to the improvements will be too small to measure, it still seems unreasonable to assume that containing the flood on one side of the channel will have no effect on the other. I would appreciate a more thorough analysis from the Corps concerning possible scouring action or other long term effects caused by the improvements (during both normal and flood times) which may lead to accelerated deterioration of the western bank, and hence the towpath.

The continued integrity of the Blackstone Canal is of great importance to us. Long neglected, interest in the canal is now increasing among the communities bordering it, and among various state and federal planning agencies. The canal will be the subject of a major conference in May (the Corps is being invited to participate), and we are hoping to discuss the possibility

of a linear park incorporating the canal. The National Park Service, interested in the creation of urban linear parks, visited the canal last fall as a candidate for national park designation.

Please let us know if you have any questions or require further information.

Yours truly,

Frederick C. Williamson

Frederick C. Williamson
State Historic Preservation Officer

FCW/ekh

cc: Mr. Tannenbaum
Mr. Klyberg

FERNAND J. ST GERMAIN
1ST DISTRICT, RHODE ISLAND

2136 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515

200 JOHN E. FOGARTY BUILDING
PROVIDENCE, R.I. 02903
TEL.: 528-4323

Congress of the United States
House of Representatives
Washington, D.C. 20515

COMMITTEES:
BANKING, CURRENCY AND HOUSING
CHAIRMAN, SUBCOMMITTEE ON FINANCIAL INSTITUTIONS SUPERVISION, REGULATION AND INSURANCE
GOVERNMENT OPERATIONS
SMALL BUSINESS

July 12, 1977

Colonel John P. Chandler
Division Engineer
Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Chandler:

I am enclosing a copy of a memorandum forwarded to me by Mr. George R. Bennett of the Pawtucket-Blackstone Valley Chamber of Commerce, which was prepared for members of that office's Board of Directors and other affected parties.

You will note that Mr. Bennett's memorandum concerns comments following review of the preliminary flood control plan prepared by the Army Corps of Engineers. I would welcome your comments on Mr. Bennett's paper especially as it concerns the benefit cost ratio computation.

Mr. Bennett refers to very adverse effects on industries, as many as forty, should a sewer line burst because of flooding conditions.

I welcome your comments on this matter.

Sincerely,

Fernand J. St Germain
Member of Congress

FJStG/isl
Enc.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Division of Ecological Services
P. O. Box 1518
Concord, New Hampshire 03301

September 22, 1977

Division Engineer
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

A copy of our Conservation and Development Report concerning local flood protection along the Blackstone River at Berkley, Rhode Island is enclosed for your information and files.

Sincerely yours,

Gordon E. Beckett
Supervisor

Enclosure

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Division of Ecological Services
P. O. Box 1518
Concord, New Hampshire 03301

BLACKSTONE RIVER AT BERKLEY, RHODE ISLAND

Conservation and Development Report of the U.S. Fish and Wildlife Service, on a study for urban flood control, floodplain management, water supply, and recreation of the New England Division, U.S. Army Corps of Engineers.

The study was authorized by a resolution of the Senate Committee on Public Works adopted 29 May 1968, under Section 3 of the Rivers and Harbors Act. This report is prepared under authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.), in cooperation with the Rhode Island Division of Fisheries and Wildlife. A Preliminary Report on the Narragansett Bay and Pawcatuck Drainage Areas was issued by this Service on October 29, 1968.

The local flood protection project at Berkley provides for the construction of earth dikes and concrete floodwalls along the left bank of the Blackstone River in Cumberland, Providence County, Rhode Island. The project would extend from river station 280+00 (approximately 2 miles above Valley Falls Pond) to river station 320+00; a distance of about 4,000 feet. The plan of protection would provide for construction of 3,800 feet of earth dikes, 1,450 feet of concrete floodwall, a pumping station, a vehicular ramp over the dike at Martin Street, a vehicular gate, two railroad stoplog structures, interior drainage, and other appurtenant works. The project would provide protection for the 40-acre industrial park located on the east bank of the Blackstone River. The dikes in general would have a top width of 10 feet and slopes of 2.5 on 1 both landside and riverside. Slope protection will consist of 15 inches of protection stone on 12 inches of gravel bedding on the riverside and 6 inches of seeded topsoil on the landside. The dike will be 16 feet high and 3,800 feet long.

The floodwall will be an I-type floodwall with sheet piling cut-off for seepage control. The height of the wall along the river's edge would be approximately 16 feet. The 1,450 feet of concrete I-type concrete floodwall would be constructed along the river face of the existing 42-inch sanitary sewer main with transition changes at each end to earth dikes.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

A pumping station, for discharge of interior drainage, seepage, and industrial wastewater will be located at the downstream side of the Martin Street Bridge.

The area of the proposed dike consists of industrially-zoned land located along and adjacent to the Blackstone River. The 40-acre tract to be protected is primarily devoted to industrial buildings, roadways, and parking lots. Those areas not occupied by the various industries and commercial operations consists of open fields having a cover of grass. Riparian vegetation, approximately 8 acres, is primarily native grasses with a sparse fringe of oak, sycamore, and birch trees with blackberries and shrubs interspersed. An area at the rear of the Health-Tex building is occupied by a thick cover of birch, blackberries, and native grasses.

While not overly significant this riparian vegetation does provide habitat for wildlife within an urban-industrial setting. Wildlife species such as pheasant, woodcock, cottontail rabbit, woodchuck, and a variety of songbirds may be found within the project area.

The Blackstone River currently supports a warmwater fish population which has a low recreational value due to pollution. Principal fish species in the project vicinity include goldfish, white suckers, and common sunfish. With pollution reduction and restoration of freshwater fisheries potential, the lower Blackstone could support a warmwater fishery based upon largemouth bass, chain pickerel, and possibly northern pike. With extensive access and a return of alewife and possibly shad, the lower river fishery could be expanded many fold.

The project is not expected to have a significant impact upon fishery resources. However, construction of the flood protection dike and I-walls will destroy approximately 8 acres of riparian wildlife habitat.

In summary, the project, as planned, affords no outstanding benefits to fish or wildlife. In general, due to the urban character of the area and the low fishery values because of pollution, the project will have no severe adverse impact upon fish and wildlife resources. Commitments of fish and wildlife resources are limited to the loss of streambank vegetation and associated wildlife displaced by the dike and floodwall structures.

No feasible method for direct prevention of the anticipated loss of riparian habitat appears possible without altering the planned design and operation of the project. However, possibilities for mitigation of some losses are evident. Planting the landside face of the dike with vegetative species valuable to wildlife would be effective in mitigating anticipated damages. Ground cover plants of value to wildlife of the area would be white clove and reed canary grass, or a commercial forage mixture containing red clover, alsike clover, timothy and red top known to seed outlets as "Forage Mixture 1 and 2." Desirable shrubs for the area would be autumn olive or fragrant sumac. Assuming public access is assured,

this measure will provide an area for bird watchers, wildlife photographers, naturalists, and school children with an opportunity to observe wildlife without requiring extensive travel.

In the future, with pollution reduction, the quality of water within the Blackstone River will be improved to meet the biological requirements of fish native to the Blackstone Basin. With revival of this fishing opportunity, fishermen from Berkley, Cumberland, and the Blackstone Basin, as a whole, will be in need of streambank access.

There is opportunity, in connection with the construction of the dike and floodwall which parallels the river, to contribute to development and utilization of future fishery resources. Provision of public access and use of the project rights-of-way, and modification of the project and improvement to include a canoe and cartop boat launching facility would insure maximum project benefits.

Average annual fisherman use would be approximately 3,800 fisherman days with an average annual equivalent value of $3,700.

We estimate that the parking space required for those actually fishing at peak periods will require 1.0 acre of area in order to accommodate bank and boat fishermen. It may be possible through use agreements to utilize existing parking space provided by industries within the industrial park.

Benefits from the proposed fishermen access would not be realized until pollution reduction is achieved and fisheries management programs are implemented. In the interim, canoests and others who desire to float the river will benefit from the access and launching facility.

Therefore, the U.S. Fish and Wildlife Service recommends that:

(1) Public access and use of project rights-of-way along the Blackstone River, except areas reserved for reasons of safety of the public or project operation, be provided.

(2) The landside face of the dike be planted with vegetative species valuable to wildlife.

(3) At least one canoe and cartop boat launching facility and parking area be provided.

We do not plan to make additional studies of this project nor prepare any additional reports unless the project plan involves improvements and methods different from those described above.

Date signed: September 22, 1977

Fred Benson
Project Manager

Gordon E. Beckett
Supervisor

State of Rhode Island and Providence Plantations
EXECUTIVE CHAMBER, PROVIDENCE

J. Joseph Garrahy
Governor

November 17, 1978

Colonel John P. Chandler
Department of the Navy
New England Division
424 Trapelo Road
Waltham, MA 02154

Dear Colonel Chandler:

The Governor has asked me to thank you for your kind invitation to attend the water resources meeting on December 7.

I regret to inform you that the Governor will be unable to join you on that date due to a previously scheduled commitment.

The Governor has asked Anne Stubbs, Policy Assistant to represent him.

Warmest personal regards.

Sincerely,

William G. Dugan, Jr.

William G. Dugan, Jr.
Executive Assistant
to the Governor

State of Rhode Island and Providence Plantations
EXECUTIVE CHAMBER, PROVIDENCE

J. Joseph Garrahy
Governor

November 20, 1978

Colonel John P. Chandler
Division Engineer
Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Colonel Chandler:

Thank you for advising me of the feasibility stage public meeting on water and related resources for the Blackstone River Watershed. This meeting will provide both federal and state officials with the opportunity to learn of the results of the Blackstone River Watershed and to obtain the views and comments of the public on the Corps' recommendation for construction of a local protection project at Berkley.

I regret that I will be unable to attend this meeting on December 7. I have asked Ted Green of my staff to attend and report on the Corps of Engineers' presentation and on the public response to the Corps' proposal.

Again, I thank you in advance for providing Rhode Island's citizens with the opportunity to review and comment on the Corps' proposal for a flood management program along the Blackstone River.

Sincerely,

J. Joseph Garrahy
GOVERNOR

FERNAND J. ST GERMAIN
1ST DISTRICT, RHODE ISLAND

2136 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515

200 JOHN E. FOGARTY BUILDING
PROVIDENCE, R.I. 02903
TEL.: 528-4323

Congress of the United States
House of Representatives
Washington, D.C. 20515

COMMITTEES:
BANKING, FINANCE AND URBAN AFFAIRS
CHAIRMAN, SUBCOMMITTEE ON FINANCIAL INSTITUTIONS SUPERVISION, REGULATION AND INSURANCE
GOVERNMENT OPERATIONS
SMALL BUSINESS

November 20, 1978

Colonel John P. Chandler
Division Engineer
Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Chandler:

This is to acknowledge receipt of your communication dated November 8, 1978, advising me of a feasibility stage public meeting regarding the water and related resources study for the Blackstone River Watershed in Massachusetts and Rhode Island and a concurrent public hearing for Section 404.

Unfortunately, I shall be in Washington for that entire week regarding organization of the new Congress and, therefore, I shall be unable to be in attendance on December 7th, 1978.

Again, I regret not being able to be present for this meeting.

Sincerely,

Fernand J. St Germain
Member of Congress

FJStG/jg

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

HISTORICAL PRESERVATION COMMISSION
Old State House
150 Benefit Street
Providence, R. I. 02903
(401) 277-2678

November 21, 1978

Col. John P. Chandler
Division Engineer
Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

RE: Berkeley Local Protection Project
Cumberland, R.I.

Dear Col. Chandler:

This office has reviewed the information pamphlet prepared for the feasibility stage public hearing scheduled for 7 December 1978. We recommend that the Environmental Assessment described in the pamphlet be submitted to this office as soon as possible for review and comment.

In a letter to Mr. Joseph Ignazio dated 5 April 1977 (copy enclosed), we noted that the proposed project would have an effect on the adjacent Blackstone Canal, a property listed on the National Register of Historic Places. The letter requested specific information on the physical effects of the protection project on the western bank of the river. According to the summary contained in the pamphlet, the effect of the project on historic resources was not considered, and this would appear to be an omission.

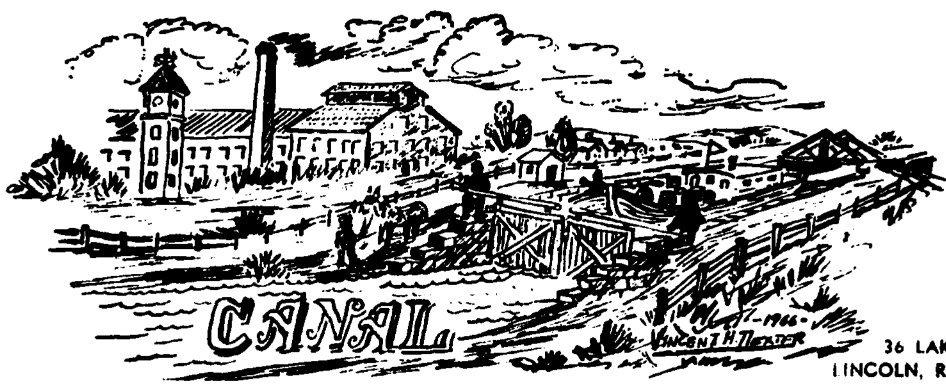
Sincerely,

Eric Hertfelder
Deputy State Historic
Preservation Officer

/dn

Enclosure

COMMITTEE FOR THE ADVANCEMENT OF NATURAL AREAS IN LINCOLN



36 LAKEVIEW AVENUE
LINCOLN, RHODE ISLAND 02865

December 1, 1978

John P. Chandler,
Colonel, Corps of Engineers
Division Engineer
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Re: Feasibility of a Dike on the Cumberland side of the Blackstone River, opposite the Town of Lincoln

Dear Colonel Chandler:

Reference is made to your announcement dated November 9, 1978 relating to the above matter. We feel that to build on the flood plain is to invite disaster. Those who have built in these areas have found this to be true. We do not believe prospective homeowners or industrialists should be lulled into a false security by the building of dikes. Witness the West Virginia flood wherein people relied on the dikes to protect them only to find millions of dollars of property damage was suffered as a result of these false hopes.

Your report states that these flood plains could continue to develop and expand thus necessitating the need for flood protection measures. However, TO BUILD ON THE FLOOD PLAIN IS TO INVITE DISASTER!

Eventually we must implement land use laws which will not strip the land of its vegetation and create erosion in the flood plain. Let's turn these areas into parks or leave them in their natural state to do the work preordained to them. Dams, levees and flood walls are not the cure-all against flood damage. We need strong local laws to prevent encroachment on the flood plains of our streams and rivers. We should not seek nor can we ever attain 100 per cent flood control.

Colonel John P. Chandler

We would appreciate receiving a copy of your environmental impact statement as we are certain that disasterous environmental effects will result in areas such as Lincoln, Central Falls and Pawtucket as the dike will serve to intensify the waterway currents increasing danger of destruction downstream during a storm.

Inasmuch as these dikes are to be subsidized by the government and paid for by all members of our society rather than the handfull of industries and developers who would benefit from them, we feel the cost/benefit ratio would not be favorable to the taxpayer.

We are especially concerned about the towpath of the Blackstone Canal. During flood time if a dike was built on the Cumberland side of the river the water would be forced to the Lincoln side and undoubtedly the towpath would be destroyed. This area has been designated a National Historic Site and any federal funds designated for use on the dike could be withheld if the canal site was in danger of being destroyed.

For the above reasons we question the advisability of creating dikes along the Blackstone River.

Sincerely,

Ruth B. Tetreault
Ruth B. Tetreault,
President,
C.A.N.A.L., Inc.

cc: Senator John F. Chafee
Senator Claiborne Pell
Providence Preservation Society
R. I. Historical Society

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
NORTHEASTERN AREA STATE AND PRIVATE FORESTRY
370 REED ROAD — BROOMALL, PA. 19008
(215) 596-1672

1950
December 4, 1978

Mr. John P. Chandler
Colonel, Corps of Engineers
Division Engineer
Department of the Army
424 Trapelo Road
Waltham, MA 02154

Dear Mr. Chandler:

Refer to: NEDPL-BC, Feasibility Study,
Blackstone River Watershed, RI & MA

As this Study declares, "This project . . . . may encourage industrial growth in the area" - the Blackstone River flood plain. Valuable natural resources, including fuel, wood and minerals, will be devoted to industrial construction. For accurate assessment of the benefits of the project in relation to costs, we believe that the Corps should give adequate weight in the calculations to:

1. The cost of subsidies for flood insurance.

2. Damage to industrial property and injury to workers, in plants built after the project is completed, from eventual floods.

Thank you for the opportunity to review this study.

Sincerely,

DALE O. VANDENBURG
Staff Director
Environmental Quality Evaluation

SUMMARY OF 7 DECEMBER 1978 PUBLIC MEETING

On 7 December 1978 a Public Meeting was held at the Ashton School in Cumberland, Rhode Island on the Blackstone River watershed. Colonel Scheider was the hearing officer. The panel at the meeting consisted of Colonel Scheider, George Bennett of the Blackstone Valley Chamber of Commerce, Frank Stetkiewicz, Town Administrator of Cumberland, Rhode Island, Paul A. DiPietro and Larry Bergen of the Basin Management Branch.

George Bennett introduced the Corps of Engineers representatives and reviewed the study history. Colonel Scheider added remarks regarding the conduct of the meeting and the purpose of the study and Paul DePietro gave a technical presentation of the findings of the study. Also in attendance for the Corps of Engineers were:

Arthur Doyle   Del Kidd   Walter Mackie   Lee Buress

Mr. Reed and Mr. Khanna of C. E. Maguire were also in attendance.

The following is a quick summary of the nine presentations made at the meeting:

Dan Varin of Rhode Island Statewide Planning made a presentation for the Governor of Rhode Island supporting the project. He noted, however, that the State prefers nonstructural measures but that Berkeley is an exception.

Charles E. Redman from the Lincoln Town Council was opposed to the project because it would affect the Lincoln water supply wells, it would raise stages downstream in the Lonsdale area, it didn't protect any residents and the railroad didn't provide any passenger service. He also referred to washouts along the canal in the past and the fact that the project would make this condition worse.

Morris Trudeau, Town Engineer for Lincoln, stated he had no formal protest but did have three specific questions. The first was a concern for the protection for the canal banks. The second was the effect of the project on established flood insurance regulation elevations and the third was whether the operation of the sanitary sewer sluice gates would normally be dumping sewage flows into the river.

Clarence Gaudette, Executive Director of the Blackstone River Watershed Association had a series of about 20 slides. The slides dealt with all of the dumps, fills, and encroachments up and down the river from Woonsocket to the mouth. He was opposed to the project because it would unnecessarily constrict the channel and cause problems downstream and on the Lincoln side.

A. Russell Webster, consulting engineer for the J. H. Lynch and Sons Corporation who are industrial developers with several plants along the river was next. As a representative of the developers he was concerned with downstream flood conditions which would be worsened by the project and as they would relate to flood insurance requirements of the plants.

Philip Neeland from Northbridge, Massachusetts was there representing their Conservation Commission. He felt that there should be further study along the upper river in Massachusetts. He wondered if the use of the Blackstone Canal in the Northbridge area, which is currently blocked off, could be used for flood control storage. He also asked how the Corps could prod towns into enforcing flood insurance regulations and what we could do about filling to prevent further encroachment.

Leo Raymond represented Juice Service, Inc. and Maplehurst Farms. The firms that he represented were in Lincoln about 50 feet from the Blackstone down in the Lonsdale area. He and five speakers before him were opposed to the project.

The last presentation was made by Colonel Scheider at the request of Chairperson Margaret Pederson of the Cumberland Conservation Commission. Colonel Scheider read the letter which we had recently received from the Committee for the Advancement of Natural Areas in Lincoln (CANAL), which opposed the project.

At the close of the meeting there was a short question and answer session in which the Corps panel responded to questions that had been raised by the speakers. Many of the questions dealt with the effect of the project on raising water levels and increasing velocities, but most of this concern had been lessened by Colonel Scheider's statement at the beginning of the meeting that we in the Corps were also concerned with the potential for increased stages and velocities and we were studying this in detail now and throughout the design stage. There was concern by Mr. Trudeau that there might be unwarranted discharges of sewage waste into the river during flood periods. We explained to him after the meeting that the gates would only be closed on either side of the levee in the event of a break on the sewerline, but that normally the sewer would continue to flow. We owe Mr. Trudeau a letter responding to that and to his other two comments.

The project is supported by the town of Cumberland and by the Governor's office. On the Lincoln side of the river there is either no interest in the project, because no one on the Lincoln side benefits or there is strong opposition, because of a concern that the project might have an adverse effect on the Lincoln side. One other consideration that we will have to deal with is the possibility that because of opposition to the project, that more than an environmental assessment will be necessary.

CORRESPONDENCE SINCE THE

7 DECEMBER 1978 MEETING

CORRESPONDENCE SINCE THE
7 DECEMBER 1978 PUBLIC MEETING

Letters From:

State of Rhode Island, Statewide Planning Program - 7 December 1978

Town of Lincoln, Conservation Commission - 8 December 1978

Town of Cumberland, Town Administrator - 15 December 1978

City of Central Falls, City Engineer - 21 December 1978

Town of Lincoln, Town Council - 21 December 1978

Town of Lincoln, Town Council - 19 January 1979

Town of Lincoln, Town Council - 22 February 1979

Town of Cumberland, Town Administrator - 18 September 1980

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

Department of Administration
STATEWIDE PLANNING PROGRAM
265 Melrose Street
Providence, Rhode Island 02907

December 7, 1978

Col. John P. Chandler
Division Engineer, New England Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02154

Dear Col. Chandler:

I have been asked to comment, for Governor Garrahy, on the flood protection measures for the Blackstone River watershed that are currently under consideration. These comments are submitted in response to your "Announcement of a Feasibility Stage Public Meeting" dated November 9, 1978 (NEDPL-BC).

As a general policy, non-structural measures should be used to prevent development of areas subject to flooding and the resulting hazards to persons and property. The area that would be protected by the proposed Berkeley Local Protection Project, however, represents a valid exception to this general policy. This area has been developed by several industrial facilities which make a substantial contribution to the state's economy. We therefore support the use of a combination of structural and non-structural measures as proposed in the announcement of November 9, in this situation.

If this proposal is to achieve its objectives, the communities concerned must enact regulations for areas subject to flooding that go beyond the minimum requirements of the National Flood Insurance Program. This is called for in the proposal by non-structural measure number 3, but should be given even greater emphasis. The flood plain regulations adopted by the communities along the Blackstone River generally deal only with flood proofing of structures. They do not address questions of appropriate use of areas subject to flooding. Rhode Island's zoning enabling act authorizes communities to regulate the use of such areas and to prohibit inappropriate uses. The communities concerned, however, must adopt regulations under this authorization.

The effect of the project on the Martin Street Bridge should be clarified. This bridge provides the only crossing of the Blackstone River between Lonsdale and Albion for local traffic. It is essential to serve the residential areas and industries that have located on both sides of the river.

Both state and local plans call for the provision of a linear conservation and recreation area along the Blackstone River and canal. Provision for continuity of pedestrian movement along the river and canal should be incorporated into the project.

This project clearly demonstrates the need for adequate planning for and regulation of areas subject to flooding. The location of several major industrial facilities in an area clearly not suitable for such development has led to the need for a project now estimated to cost almost $4.5 million. Since the area to be protected is about 40 acres, this means that the cost of protection will average about $111,200 per acre. This is far too high a price to pay for industrial land. Therefore, although we support the proposed Berkeley Local Protection Project, this support should not be construed as encouraging future development of other areas that are subject to comparable flood hazards.

Yours very truly,

Daniel W. Varin
Chief

DWV/rc

cc: Ms. Anne Stubbs

Town of Lincoln

100 OLD RIVER ROAD

LINCOLN, RHODE ISLAND 02865

CONSERVATION COMMISSION

December 8, 1973

Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

re: Berkeley Local Flood Protection Project, Cumberland, R.I.

Dear Sirs:

I recently attended the public hearing held on December 7, 1973 at the Ashton School, Cumberland, R.I. concerning the proposed flood control project in Berkeley, R.I. Although I made a few vocal comments at that time I am also submitting this letter to fully describe our objections to this project.

It is the opinion of the Lincoln Conservation Commission that the Berkeley Local Protection Project is not feasible from an environmental or economic viewpoint. We view the project to be a distinct threat to the integrity of the Blackstone River floodplain system and adjacent areas, especially on the Lincoln side of the river.

One disadvantage, at this time, is fully understanding all the possible ramifications of the project without available data in the form of an Environmental Impact Study. It was stated at the hearing that an Impact Study is not planned at this time because significant impact to the environment is not foreseen. However, also stated in the National Environmental Policy Act of 1969 is the following:

> "Prior to making any detailed statement, the responsible Federal official shall consult with and obtain the comments of any Federal agency which has jurisdiction by law or special expertise with respect to <u>any</u> environmental impact involved."

If not already done, we request that your division consult with the Environmental Protection Agency and the Department of the Interior as to the necessity of filing an Environmental Impact Statement. We do not believe the decision to file should be left to the discretion of the Army Corps of Engineers. In a related area, the Wetlands Division of the Rhode Island Department of Environmental Management should

also be consulted as to the applicability of this project under the Rhode Island Wetlands Act.

We appreciate that you are preparing an Environmental Assessment of this project and we request that a copy of this report be forwarded to the Lincoln Conservation Commission upon completion. Regarding this assessment, we also request that the following information be addressed:

I. Cost-Benefit Analysis:

It is understood that the cost/benefit ratio for this project is 1.5/1. We would be interested in learning how this figure was attained, with the following considerations:

A. It is our opinion that only three facilities would directly benefit by this project. Peterson-Puritan Inc. and Gracious Living would not benefit and should not be included in the analysis.

B. The railroad in this area would be protected by the project, however, flood waters would damage or prohibit use of the line in other areas, for example in the vicinity of Mendon Road, before any effect in the Berkeley area would be realized. Therefore, any economic benefit to the railroad should not be included.

C. The local recreation area known as Berkeley Oval Park would not be permanently damaged by flooding and any benefit to the park should not be included.

D. It is probable that the $4.4 million cost of the project will increase over the time period before construction begins. How will this increase affect the cost/benefit ratio?

II. Environmental Considerations:

The following potential impacts should be addressed in the Assessment:

A. How will the loss of 40 acres of natural floodplain affect flood levels above and below the project area? Potential impact of higher flood levels downstream must be assessed with regard to the J.M. Mills landfill which has previously altered the floodplain. Removal of additional floodplain in the Berkeley section will further strain the natural flood protection already significantly affected by the landfill.

B. How will the increased velocity of flood waters affect adjacent areas?

C. How will the diversion of water away from the Cumberland side, coupled with increased velocity, affect the Lincoln side? Of concern is the integrity of the Blackstone Canal and towpath - a national historic site, and potential recreational area for the Town of Lincoln.

D. What will be the impact on fish and wildlife habitat in the area?

E. What will be the impact during construction regarding water, air and noise pollution?

F. What will be the impact on aesthetics, also with regards to the potential recreational use of the Blackstone Canal?

III. <u>Alternatives</u>:

A requirement of Environmental Impact Statements is that all possible alternatives to a project be fully analyzed. In your assessment alternatives should be reviewed, including relocation and/or flood-proofing of facilities involved.

We understand that some of these considerations have already been examined in your environmental assessment. However, please realize that we are extremely concerned about all of the potential impacts from this project to the Town of Lincoln and the Blackstone River Watershed. All of the above matters should be fully considered in order that we might adequately analyze the project.

Upon receipt of the Environmental Assessment we shall again submit a letter regarding any further concerns.

Thanking you in advance for your consideration, I remain

Sincerely,

Richard W. Enser

Richard W. Enser, Chairman
Lincoln Conservation Commission

Two copies enclosed.

Copies to: Lincoln Town Council

Cumberland, Rhode Island

OFFICE OF THE TOWN ADMINISTRATOR
TOWN HALL
CUMBERLAND, R. I. 02864

FRANCIS R. STETKIEWICZ

December 15, 1978

Colonel John P. Chandler
Division Engineer
Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

My Dear Colonel Chandler:

The Town of Cumberland has agreed with the Department of the Army to participate in a flood protection system along the Blackstone River in the Berkeley section of the Town. This project has been termed "economically justified" by the New England Division of the United States Corps of Engineers.

The protective system will consist of earth dikes, steel sheet piling, concrete walls, two railroad gates, one vehicular gate, ramp at Martin Street and other appurtenances.

The preliminary plans for this project were prepared by the Corps of Engineers and approved by Edward J. Hayden, former Town Administrator.

The project will afford protection to the height of standard project flood for the P & W Railroad, the Town of Cumberland pumping station and well off Martin Street, Health-tex, Okonite Company, Roger Williams Foods, Owens-Corning Fiberglas, and three other industrial plants.

On behalf of the Town, I hereby wish to express the Town's ability and willingness to contribute to the project costs, subject to Town Council approval, appropriate funding at the Annual Financial Town Meeting, and to provide the required assurances of local cooperation and participation prior to actual construction as outlined below:

A. Provide without cost to the United States, all lands, easements, and rights-of-way necessary for the construction and maintenance of the project, currently estimated at $192,000.00.

B. Hold and save the United States free from damages due to construction works except damages due to the fault or negligence of the United States or its contractors.

Colonel John P. Chandler
Army Corps of Engineers
Page Two
December 15, 1978

C. Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army, currently estimated at $24,200.00 annually. (See enclosed Table F-2).

D. Prescribed and enforce regulations to prevent encroachment on both the improved and unimproved channels, and manage all project related functions.

E. Comply with the provisions under Section 210 and 305 of Public Law 91-646, 91st Congress, approved January 2, 1971, entitled "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970."

Sincerely yours,

Francis R. Stetkiewicz

Francis R. Stetkiewicz
Town Administrator

FRS:hm

INCORPORATED 1895
City of Central Falls
RHODE ISLAND 02863
-
ADMINISTRATIVE OFFICES
CITY HALL

December 21, 1978

Department of the Army
N.E. Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Attn: John P. Chandler
Colonel, Corps of Engineers
Division Engineer

Subject: Proposed Berkeley Local Protection Project

Dear Sir:

In response to the proposed Berkeley Local Protection Project the following questions are raised in regards to the possible adverse affect upon the City of Central Falls.

The Flood Plain Information Study, completed in 1971 by the Corps of Engineers, covers the towns of Cumberland and Lincoln, and the cities of Pawtucket and Central Falls which comprise the lower portion of the Blackstone River Basin. According to this study most of the flood plain area is located between the George Washington Highway Bridge in Cumberland, and the Broad Street Bridge in Central Falls.

The larger flood plains within this section are the new pond area, which has lost its effectiveness with the application of extensive fill and the conduct of a sanitary land fill operation. Thus, the Valley Falls Pond area, adjacent to Central Falls, is the only large effective flood plain which can retard and store flood waters.

I would quote the following paragraph from the 1971 Flood Plain Information Study. "Appropriate consideration should be given to the possible future occurrence of historic floods, the intermediate regional flood, and the standard project flood in problems concerned with the control of developments in the flood plains of the lower Blackstone River, and in reaching decisions as to the size of floods to consider for this purpose."

Various portions of the lower Blackstone River are affected by the intermediate regional flood among which are portions of Central Falls and the Berkeley area of Cumberland. In effect the intermediate regional flood areas retard and store flood waters reducing the danger of the standard project flood.

The proposed introduction of approximately one mile of dikes along the East bank of the Blackstone River would eliminate many acres of flood storage areas and create a hydraulic constriction two miles upstream of the City of Central Falls. It is apparent that a flood crest will move much faster to Central Falls with considerable less time for flood emergency preparation.

The area in the vicinity of Central Falls is being assigned a progressively greater part in the retainage and storage of flood waters. Therefore, would it not be feasible to develop the Valley Falls Pond area into a flood control Reservoir? Would this not be required in order to compensate for the loss of the large flood plain at new pond, the various encroachments along the banks of the river and the possible additional loss of intermediate flood storage in the Berkeley area.

Respectfully,

Walter Karpowich

Walter Karpowich, P.E.
Central Falls City Engineer

WK:gb

CC: Mayor Bessette
Francis Stetkiewicz,
Town Administrator, Cumberland

TOWN COUNCIL

Town of Lincoln

100 OLD RIVER ROAD

LINCOLN, RHODE ISLAND 02865

CLIFFORD HOWARTH
COUNCIL PRESIDENT
15 COLONIAL DRIVE
LINCOLN, R. I.

COUNCILMEN
CHARLES E. REDMAN · SAYLESVILLE
EDDY DEL GRANDE · LIME ROCK
JOHN R. BIGONETTE · ALBION
WILLIAM CARON · MANVILLE

DAVID WILKIE · TOWN CLERK

December 21,1978

Department of Army
424 Trapelo Road
Waltham,Massachusetts 02154

Gentlemen:

Please be advised that at a Meeting of the Town Council of the Town of Lincoln,Rhode Island, held on December 19,1978, it was voted to communicate with you to request that a Meeting to include the Town Councils of the Town of Lincoln and the Town of Cumberland and your body be held for the purpose of discussing the proposed Dike to be built on the banks of the Blackstone River in the Town of Cumberland,R.I.

The members of the Town Council feel that they have many questions regarding this subject and feel this will give them an opportunity to have them answered.

Hoping you give this request your utmost attention, I remain;

Very truly yours;

David Wilkie
Town Clerk
100 Old River Road
Lincoln,R.I. 02865

LINCOLN HAS
LAND, LABOR AND TRANSPORTATION FACILITIES FOR INDUSTRIAL DEVELOPMENT

TOWN COUNCIL

Town of Lincoln

100 OLD RIVER ROAD

LINCOLN, RHODE ISLAND 02865

CLIFFORD HOWARTH
COUNCIL PRESIDENT
15 COLONIAL DRIVE
LINCOLN, R. I.

COUNCILMEN
CHARLES E. REDMAN SAYLESVILLE
EDDY DEL GRANDE LIME ROCK
JOHN R. BIGONETTE ALBION
WILLIAM CARON MANVILLE

DAVID WILKIE TOWN CLERK

January 19,1979

Department of the Army
424 Trapel Road
Waltham,Massachusetts 02154

Gentlemen:

On December 21,1978, I wrote to your Office requesting a Meeting to include the Town Councils of the Town of Lincoln and the Town of Cumberland and the Army Corp of Engineers for the purpose of discussing the proposed Dike to be built on the banks of the Blackstone River in the Town of Cumberland,Rhode Island.

As of this date I have not received an answer, therfor at a Town Council Meeting of the Town Council of the Town of Lincoln, held on January 16,1979, I was instructed to communicate with your Office to renew our request for this Meeting.

Awaiting a reply, I remain;

Very truly yours;

David Wilkie

David Wilkie
Town Clerk
100 Old River Road
Lincoln, R.I. 02865

TOWN COUNCIL

Town of Lincoln

100 OLD RIVER ROAD

LINCOLN, RHODE ISLAND 02865

CLIFFORD HOWARTH
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15 COLONIAL DRIVE
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CHARLES E. REDMAN SAYLESVILLE
EDDY DEL GRANDE LIME ROCK
JOHN R. BIGONETTE ALBION
~~WILLIAM CARON~~ Roger Valois MANVILLE
DAVID WILKIE TOWN CLERK

February 22, 1979

Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Attention Joseph L. Ignazio, Chief Planner

Gentlemen:

Thank you for your letter dated February 7, 1979 advising the Town Council of the Town of Lincoln that you will meet with the Towns of Lincoln and Cumberland as soon as you have definite answers regarding the impact of the proposed Berkely Local Protection Project on the Blackstone River in the Towns of Lincoln and Cumberland.

The Lincoln Town Council is looking forward to this meeting and expressed their thanks to you for considering this request at a Council meeting held on February 20, 1979.

Very truly yours,

David Wilkie
Town Clerk
100 Old River Road
Lincoln, R. I. 02865

LINCOLN HAS
LAND, LABOR AND TRANSPORTATION FACILITIES FOR INDUSTRIAL DEVELOPMENT

FRANCIS R STETKIEWICZ

Cumberland, Rhode Island

OFFICE OF THE TOWN ADMINISTRATOR
TOWN HALL
CUMBERLAND, R. I. 02864

September 18, 1980

Mr. Paul DiPietro, Engineer
U.S. Army Corps of Engineers
Planning Division
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. DiPietro:

Thank you for your continued efforts on the local protection project at the Berkeley area of Cumberland, Rhode Island. The planning of the Berkeley Local Protection Project has been underway for several years; the project has the general support of our town.

A Letter of Intent was sent to you based on exisiting cost sharing legislation. That level of funding was acceptable and mutually agreed upon and throughout the planning there was no indication of a larger contribution. Now based on current administration cost sharing policies, our contribution is significantly increased.

Although this new cost sharing policy has not had the benefit of Congressional review and approval, we have serious concern over it and cannot support it. We will support the present law but would not support the project under the proposed policy because of the serious financial burden to the community.

This is an important project to the vulnerable Berkeley area as shown after the damage from the recent January 25, 1979, storm. Considerable time and effort have been expended and we hope that the report will be transmitted promptly to Congress based on existing cost sharing legislation.

Sincerely yours,

Francis R. Stetkiewicz
Town Administrator

FRS:hm

APPENDIX 4

ENGINEERING INVESTIGATIONS

DESIGN AND COST ESTIMATES

TABLE OF CONTENTS

TABLES

APPENDIX IV

As a result of the previous stages of screening, and many reiterations of plans (see Appendix 2) the Berkeley area is the only economically and environmentally feasible area in the Blackstone River Basin to implement flood control measures. Therefore Appendix 4 will focus on the Berkeley area of Cumberland, Rhode Island.

Supporting engineering data and analysis addressing the Stage 3 formulation and plan selection process were developed for the Berkeley plan. Also included are applicable hydrology and hydraulics of the detailed plans, geotechnical investigations, cost estimates, design, and other technical data.

Topographic maps of the US Geological Survey, on a scale of 1:24,000 with 10-foot contours, were supplemented by a limited topographic survey of the studied areas. Quantities of the principal construction items were estimated on the basis of a preliminary design which would provide safe and adequate structures. Unit prices are based on current average bid prices for similar construction projects in the Rhode Island area.

To cover contingencies, construction and relocation, costs have been increased by 20 percent. Costs of engineering, design, supervision and administration are estimated lump sums based on knowledge of the project areas and experience on similar projects.

GENERAL PLAN DESCRIPTIONS

This section of the appendix is concerned with describing the plans selected in the previous section on formulation. All meaningful effects of the plans, both favorable and unfavorable, are presented. It also presents significant information on design, construction, and operation and maintenance as required for a reasonable understanding of the technical aspects of the plan. This type of broad description is presented in this section with economic information appearing in the subsequent sections.

The Berkeley area is located along the east bank of the Blackstone River, extending from River Station 280+00 to 320+00 in Cumberland, Rhode Island. Two plans of protection were investigated; a structural plan offering protection against the SPF and a nonstructural plan offering protection against the 100-year flood.

The structural plan includes construction of about 5,000 feet of earth dike embankment and concrete wall at Martin Street, two gate structures at the Providence-Worcester Railroad trackage, one vehicular gate and one pumping station with appurtenant structures to be located just downstream from the existing Martin Street Bridge. This plan would protect all the buildings and land in the Berkeley area.

The nonstructural plan is primarily intended to protect the buildings in the Berkeley area. It consists primarily of flood proofing the individual buildings by sealing the lower perimeter of each building with flood shields at the windows and doors, and waterproofing the walls of the building.

For these programs to be effective the public must understand the general flood problem, the degree of risk and the methods that can be used to control the use of the flood plains.

STRUCTURAL FEATURES - BERKELEY LOCAL PROTECTION PROJECT PLAN A

The Berkeley Local Protection Project is the only structural project feasible for implementation in the Blackstone River Basin. The following sections describe the structural features of this local protection project. Plate 3 of the main report is a plan view of the structural plan A and Plate 4 of the main report shows the cross section details.

Geotechnical Considerations

Foundations and Materials Investigations - Four borings, each about 25 feet deep, were made for the Berkeley project. Split spoon soil samples were taken and selected samples were classified and tested. Where applicable, information was used from borings done for the Blackstone Valley Sewer District Commission in connection with the Cumberland branch interceptor. Several of these borings are located along the alignment of the barrier.

Site Geology - Most of the local protection project is located on an alluvial plain comprised primarily of sand and gravel. The ends of the barrier extend landward to the adjacent rising terrace deposits along the side of the river valley. The deposits in the alluvial plain are at least 30 feet thick and are underlain by quartzitic type bedrock at an undetermined depth.

Foundation Conditions - The design for the Berkeley site consists of 10 to 20-foot high earthfill dikes and a section with a concrete floodwall. The top barrier varies from elevation 87.5 feet at Station 0+00 to 78 feet at Station 51+00. Part of the alignment is along a buried 42-inch sewerline. The sewer will not be disturbed.

Dikes - The dikes will be founded on interlayered silty and gravelly sands and sandy gravels. Stripping of several feet of unsuitable surface materials may be necessary in places. The overburden appears adequate to support the proposed structures.

Concrete Floodwall - A concrete I-Wall with a sheet pile cutoff extends from Station 5+50 to Station 20+00. Silty sands and sandy gravels are indicated to a depth of 25 feet and should provide adequate bearing for the proposed structures.

Pertinent Data

Purpose - Flood Protection

Location of Project

State	Rhode Island
County	Providence
Town	Cumberland
River	On the Blackstone River approximately two miles upstream from Valley Falls Pond in Valley Falls, Rhode Island.

Drainage Area - Blackstone River Basin Drainage Area at local protection site - 436 square miles.

Streamflow Data - At the Woonsocket gaging station during the period of record through December 1973, monthly runoff from the 416 square mile drainage area varied from 270 to 1,519 cfs with a mean of 725 cfs. The maximum flood of record for the Blackstone River at Woonsocket is 29,600 cfs, August 19, 1955.

Vehicular Gate

Type	Reinforced Concrete - Steel Swing Gate Structure
Elevation	78.69 Feet, NGVD
Opening Width	40.0 Feet
Height	11.0 Feet

Railroad Gates

Type	Reinforced Concrete - Steel Swing Gate Structure
Elevation, Top Gate	78.18 Feet (South Gate), 87.5 Feet (North Gate)
Opening Width	9.25 Feet Each
Height	9.0 Feet (North Gate), 6.0 Feet (South Gate)

Pumping Station

Structure	Reinforced Concrete with Brick and Steel Superstructure
Size	26.0′ x 31′ - Bottom Elevation 55.0′ NGVD - Roof Elevation 88.0′ NGVD
Pumps	2 @ 40,000 GPM 36" x 48" at a 25 Static Head Driven by Two 400 HP Motor Operating @ 505 RPM

Embankments

Type	Reinforced Concrete "I" Wall
Elevation, Top of Wall	86.25 - 86.16 Feet, NGVD
Total Length	1,450 Feet
Top Width	1.5 Feet

Design

Dike Design - The dikes in general would have a top width of 10 feet and slopes of 2.5 to 1 on both landside and riverside. The major portions of the dikes would be constructed of compacted earthfill with slope protection consisting of 15 inches of protection stone on 12 inches of gravel bedding on the riverside and 6 inches of seeded topsoil on the landside. The project would be designed with a minimum of 3.0 feet of freeboard against the Standard Project Flood (SPF).

Floodwall Design - Concrete floodwalls would be designed in accordance with criteria established in EM 1110-2-2501, modified as necessary to fit local conditions. The floodwall would be an I-type with sheet piling cut off for seepage control. The height of the wall along the rivers edge would be approximately 16.0 feet. The I-type concrete floodwall would be constructed along the river face of the existing 42" sanitary sewer main with each end having traditional changes to earth dikes.

Channel Improvement - Channel improvement would, in general, consist of straightening the east bank to align the dike embankment. No channel excavation is planned.

Railroad Gates - Two swing gate closures would be required at the intersection of the project alignment and the Providence and Worcester Railroad trackage. The structures would have a clear opening of 9.25 feet to permit passage of freight trains through the flood protected area during normal periods. Steel swing gates would provide a closure for floodwaters in times of flood. Final design of the structure would be coordinated with the railroad company.

Pumping Station - A pumping station for discharging interior drainage and seepage would be located at the downstream side of the Martin Street Bridge. The structure would house two axial flow pumps, each capable of discharging 40,000 GPM at 25 feet of static head. The pumps would be driven by two 400 HP diesel engines through right angle gear units operating at 505 RPM. Normal runoff from approximately 270 acres high ground and industrial wastewater would be conducted to the Blackstone River through a 48-inch diameter reinforced concrete pipe. The 48-inch gravity discharge pipe would be provided with a sluice gate closure on the riverside of the

dike. During flood periods interior drainage, seepage and industrial wastewater would be pumped over the earth dike to the Blackstone River through two 48-inch diameter coated steel pipes. All necessary permits for discharge into the river will be considered during later design phases of the project.

Vehicular Ramp - A vehicular ramp will be provided at the intersection of the project alignment and Martin Street. The ramp will be constructed so that the ascending and descending grades will be 8 percent with a 50-foot vertical curve at the crest. The roadway will have two travel lanes of 12-foot width with shoulders of 3 feet on each side. The asphaltic concrete road will be laid 3 inches thick.

Vehicular Gate - A vehicular floodgate closure would be required at the intersection of the project alignment and a 70-foot right-of-way leading to proposed developable industrial property. The structure would have a clear opening of 40 feet to permit passage of vehicular and pedestrian traffic through the flood protected area during normal periods. Steel swing gates would provide closure for floodwaters in times of flood.

Relocations - Relocations required by this project consist of street lighting, overhead telephone and powerlines along 350 feet of IGA Way, 450 feet of Health Tex entranceway and 400 feet along Martin Street.

Interior Drainage - Construction of the recommended plan of protection would cause disruption of all interior drainage, drain lines and industrial wastewater that now discharges directly into the Blackstone River, necessitating the construction of the interceptor drains to the pumping station. The interceptor drain would conduct to the pumping station all interior runoff, industrial wastewater and seepage through the dikes and walls that occurs during flood periods. In normal times, water from the interceptor drain would flow by gravity through the pumping station and discharge pipe into the river. During flood periods, water from the interceptor drain lines at the pumping station would be diverted by sluice gates into the pumping inlet chamber and pumped over the dike to the river. The interceptor drain lines would be constructed of reinforced concrete pipe varying in size from 12 inches to 48 inches in diameter, Class III and V. Approximately 17 manholes and/or catch basins would be required along the interceptor drain lines at the intersection of other pipelines.

Sewer Gates - Two sewer gates will be provided where the sewerline intersects the dike going into and out of the dike area. This is to prevent interior flooding from occurring. During the flood period these sewer gates would only be closed in the event of a rupture in the sewerline inside the protected area and sewage would be bypassed into the river.

Real Estate

Site Description

Land - The area covered by the proposed dike consists of industrial land located along and adjacent to the Blackstone River. The land is generally level and consists mostly of open fields, having a cover of grass. There is a light tree line along the riverbank. Areas of heavy brush cover are located to the rear of the Health Tex building and along the Blackstone River on both sides of Martin Street.

A privately constructed earthen dike is located between the Health Tex Company parking lot and the Blackstone River. This dike is approximately 200 feet in length and varies from 5 to 10 feet above the natural grade. Along IGA Way, near the intersection of Martin Street and extending in a northerly direction beyond the Roger Williams Warehouse, is a buried sewerline. The height of the search cover on the sewerline varies from 3 to 10 feet above road grade. This sewerline is suitated in a permanent easement area owned by the Blackstone Valley Sewer District Commission. The easement is 20 feet wide and extends within the alignment of the proposed dike area for approximately 1,400 feet.

Improvements - There are no buildings located in the area of the proposed dike within the 60-foot base. However, based on the preliminary plan with a 60-foot base, access to the Roger Williams Warehouse would be impaired. With denial of access, the entire ownership would have to be acquired in fee unless the access is modified to permit adequate ingress and egress. The major improvement in this parcel is a large modern warehouse.

A portion of the private access way leading into the Roger Williams Warehouse, known as IGA Way, is situated within the 60-foot base area required for the dike. Thus, access to the warehouse would be denied. The 20-foot temporary construction easement would also interfere with access via IGA Way. Engineering provisions have been made to permit adequate access to this property.

An estimated 250 linear feet of a 6-foot high chain link fence on the Roger Williams property is also within the project area.

Located approximately midway between the railroad line and the riverbank is a 9-foot by 16-foot concrete block well and pumphouse. This pumphouse supplies water at a rate of 300 to 500 gallons per minute to the Marble Plant (Owens-Corning Fiberglas). The water is pumped from the pumphouse to the Marble Plant via subsurface cnduits.

An official of the Owens-Corning Fiberglas Company stated that the pumphouse and well is an important factor in their manufacturing process and they would prefer to have this structure protected by the proposed dike.

Site Improvements - An estimated 900 square yards of the Health Tex asphalt paved parking lot is located in the area of the proposed dike.

Utilities and Services - Electric power, telephone service, town water, sewer and police and fire protection are available to properties within the project area.

Relocations - Roads and Public Utilities - Approximately 300 feet of IGA Way and 400 feet of the Health Tex access roadway.

The electric and telephone lines and supports on the Health Tex property and along IGA Way.

The electrical and telephone lines and supports at the Health Tex parking lot that cross the river into the town of Lincoln.

Existing buried waterlines along IGA Way and possibly along the private road on the Health Tex property.

Zoning - The entire project area is zoned Industrial A. The Cumberland Zoning Ordinances prohibit numerous industrial operations in areas with this classification. Most of these prohibited operations produce a foul odor or undesirable waste products.

Tax Loss - Based on discussions with the town of Cumberland assessors, the estimated tax loss to the town would not exceed $200 per year.

Acquisition Costs - Experience in acquiring properties in other civil works projects indicates that acquisition costs will average approximately $2,000 per tract. These costs include mapping, surveys, legal description, title evidence, appraisals, negotiations, closings and administrative costs for possible condemnation. The number of ownerships within the project area was estimated from a local assessor's maps and is considered reasonably accurate. The assessor's maps indicate a total of six separate tracts in the project area. For the purpose of this preliminary estimate, an additional ownership or a total of seven ownerships will be included to allow for a pumping station site. Based on this preliminary survey, the number of ownerships and acquisition costs are estimated as follows:

7 Ownerships @ $2,000 = $14,000

Relocation Assistance Costs - Public Law 91-646, Uniform Relocation Assistance and Real Property Act of 1970, provides for uniform and equitable treatment of persons displaced from their homes, businesses, and farms by Federal and Federally assisted programs. Some of the reimbursable expenses applicable to the project area include the following: recording fees, transfer taxes

and similar expenses, mortgage prepayment penalty costs and refunds on real property taxes. In accordance with this law, an estimate of $1,400 or an average of $200 per ownership is included in this report to cover the implementation of this act.

Severance Damages - Severance damages usually occur when the remaining portion may not be subject to full economic development. The severance damages are measured and estimated on the basis of "Before and After" appraisal methods and will reflect actual losses inflicted on the remainder as a result of partial acquisition. The estimated severance damage is $10,000.

Contingencies - A contingency allowance of 20 percent is considered adequate to provide for possible appreciation of property values from the time of this estimate to acquisition date for possible minor line adjustments. It also allows for additional hidden ownerships which may develop by refinement of taking lines, for adverse condemnation awards and for practical and realistic negotiations.

Recommendations and Estates to be Acquired - It is recommended that the necessary properties be acquired in fee or by permanent easement. The owners of the properties and officials of the companies involved in the project area were contacted; and, for the most part, they concurred in the proposed plan of acquisition.

A study of the project maps and field work in the project area indicates that a 60-foot base for the dike would extend into IGA Way. Thus, access over this private right-of-way to the Roger Williams Warehouse would be eliminated. With access denied to this parcel, the entire ownership would be acquired in fee. The land and improvements are conservatively valued at about $4 million.

To avoid the acquisition of this valuable ownership, a concrete floodwall will be substituted for that portion of the dike along the west side of IGA Way to reduce the taking limits. An estimated length of 300 feet of floodwall will be required to insure access into the warehouse via IGA Way. Also, the temporary construction easements should not interfere with access over IGA Way. Properties to be acquired that are encumbered by existing easements will be purchased subject to those easements.

Temporary Construction Easement - Temporary easement of 20-foot widths are required for areas for a 2-year period. For the most part they will run continguous to the inboard toe of the proposed dike. Exceptions to their contiguity occur at certain points where the close proximity of the structures to the easements would interfere with access. The estimated areas required for temporary easements will consist of about 2-1/2 acres of land.

The costs of temporary easements are predicated upon a fair return of invested capital and an estimate of the economic tax for the use of the owner's land for a 2-year period.

NONSTRUCTURAL FEATURES - GENERAL

Nontraditional Floodwalls

Floodwalls built around an individual building are another means of nonstructural floodproofing. The floodwall heights depend on the design level and are built to be compatible with the local landscape. The walls are of concrete to resist the lateral and uplift pressures associated with flooding.

Where access openings are necessary, these openings must be provided with a floodgate to be closed during floods.

During flood conditions it is possible for precipitation, seepage, and runoff from the roof to cause water to accumulate inside the floodwalls and cause water damage to property being protected. This problem can be reduced by providing interior drainage facilities and a small pumping station to remove the water. Floodwalls should be constructed with slope protection to prevent high velocity flows from causing erosion that could endanger the wall.

Floodproofing

The major component of this program is to render existing buildings and contents in flood hazard areas less vulnerable to flood damages. This is done by decreasing the permeability of the structures by means of waterproofing and/or by closing openings either permanently or temporarily with flood shields.

In the analysis of floodproofing measures the economic principle was strictly adhered to that stipulates the tangible benefits to be derived by any measure must exceed project costs. The specific criteria applied during the evaluation process are summarized as follows:

Wood framed structures must be insusceptible to flooding above foundation walls, or raising or relocation would be required.

Nonreinforced concrete walls must withstand the calculated differential waterhead between the inside and outside walls of a building plus one foot of freeboard. For depths of flooding under consideration, reinforced concrete walls could be floodproofed without any restrictions. The height of raising a building depends on its economic benefits and would not cause adverse social and environmental impacts.

Structures exceeding the maximum wall height limitations have to be relocated. Associated relocation costs would include demolishing and removing the existing structure and renovating the existing site to an open space condition.

For consistency, all structures should be floodproofed even though only minimal flood losses might be anticipated.

The dragline, defined as the differential waterhead between the inside and outside walls of a building, was not applied in this phase of the analysis. There are too many variables such as soil permeability, drainage patterns, conditions of concrete slabs or foundation walls and seepage rate into a low level structure.

Relocation

Relocating structures, towns, or parts of a city to a location safe from anticipated flood stages is termed a "nonstructural" solution. The social, environmental and economic effects of these relocations could be considerable, and possibly greater than might result from the more common structural solutions.

Relocation of a building involves locating an existing structure, or building a new structure, at a flood free site, and then moving contents from the previous structure to the new location. Finally, either demolishing, or where possible, salvaging the existing structure, or reusing it for a less damageable susceptible use. Relocation is more advisable when frequent high stage flooding occurs.

Factors to be considered when relocating are desires of property owners, and the effect upon the community.

Acquisition

Public acquisition of flood plain land is commonly of two types, (1) acquisition of full fee title, and (2) acquisition of land use easement. Fee acquisition transfers ownership from private to public hands and thereby permits use for public purposes which presumably will be compatible with the flood hazard. Preservation of open space and development of parks are two common public uses for flood plain land acquired in fee. Acquisition in fee is most appropriate for undeveloped land or land with few structures or other facilities. For highly developed land the presence of existing structures can make acquisition much more costly and at the same time may not control development.

Acquisition of a land use easement is intended to reduce flood damage by restricting land use which is incompatible with the flood hazard. This generally means restrictions on building and filling in the flood plain. Ownership, use, access, and sometimes occupancy are

maintained by the owner, but use is restricted to the conditions of the easement. Some easements specify continuation of present uses; still others specify open type uses and list permissible types.

Acquisition in fee or easement need not be immediate, but may be gradual over time. Community contributions to loss restoration can be made contingent upon public title or easement, or acquisition can be made a continuing part of a community development program.

Rearranging Property Within an Existing Structure

The degree to which the contents of a structure can be rearranged and adequately protected depends on the depth and frequency of the flooding.

For shallow flooding, rearranging property is most beneficial to the owner. This entails the use of protective type measures where equipment and goods can be raised in place and protected without finding new locations on other floors. Where the hazard is more severe and inundation is at greater depths, the equipment and goods will need to be relocated in either the same structure or in an adjacent structure, if available.

Residual damage to the structure and its contents will remain even when property is rearranged or protected for there is the cost of cleanup. Protection of property seems to be given the most serious consideration when other measures (flood insurance) are either not physically or economically feasible, or the depth of flooding is relatively shallow. Partial protection will only be used when a better means cannot be found.

Raising Existing Structures

The principal consideration for physical feasibility is that the structure can be reaised economically. Raising in place is most applicable to structures which can be raised with low cost conventional means. Raising in place is being done primarily to wood frame type structures on raised foundations (no basement). The height selected to be raised is influenced by the 100-year flood elevation and structural stability. The additional cost to raise a structure an additional foot is small compared to the initial setup cost.

Floodflow velocity should be accounted for in the design. All utility lines should be protected against water, wind, and extreme temperature exposure which may be brought about by elevating the structure. Access to and from the structure during high water should be insured when raising walks and regrading the site. Buildings with basements below the first floor are accessible and raising the structure does not protect the basement and it is doubtful that it would be economical to reinforce many basement walls or floors to take the hydrostatic head economically.

National Flood Insurance Program

Participation in the National Flood Insurance Program (NFIP) is also a recommended nonstructural feature of the plan.

To participate in the NFIP, a local government must adopt sound flood plain management regulations which meet with Federal Emergency Management Administration (FEMA) approval. The procedure that local governments generally follow to qualify for the program is discussed below.

Generally, a local government becomes aware of its need to participate in the program when FEMA issues a preliminary map identifying special flood hazard areas. Existing developments within these flood hazard areas are required to have flood insurance before they are able to get financial aid (mortgages, improvement loans, etc.) from Federally insured, regulated or subsidized institutions. To qualify the area for flood insurance the local government must apply to FEMA to enter a temporary emergency program that provides flood insurance to existing developments at subsidized rates. The application must include tentative flood plain management regulations. The Corps of Engineers or another qualified agency then conducts a Type 15 flood insurance study using detailed hydrologic and hydraulic studies to determine the 100-year flood plain and to zone the area according to the relative flooding risk. The results are submitted to FEMA, which then issues a rate map based on the flood risk zones and specifies actuarial flood insurance rates. For future developments to qualify for the regular insurance program before expiration of the emergency program, the local government must then revise its flood plain management regulations in accordance with the refined flood plain outline and minimum Federal requirements.

This nonstructural feature of the selected plan not only reduces local economic impacts from residual flood damages but also achieves a degree of long term control over future flood damages in the basin. Sound flood plain management programs that can be implemented by local governments can be as important as structural measures in reducing flood damage. For these programs to be effective the public must understand the general flood problem, the degree of risk and the methods that can be used to control the use of the flood plains.

NONSTRUCTURAL FEATURES - BERKELEY LOCAL PROTECTION PROJECT PLAN B

Primary Nonstructural Plans - Primary nonstructural plans are alternatives addressed whenever a structural project or program alternative is considered. The nonstructural Berkeley plan would handle the flooding conditions around Roger Williams Foods, Health Tex, the Municipal Pumping Station and Okonite Company. The plan of protection will provide for a combination of "I" or "T" type floodwalls 6 to 7.5 feet high, waterproofing to levels of maximum

water contact, and vehicular stoplog gates which have a clear opening of 40 feet. All proposals will provide protection against an event which has a 1 in 100-year probability of occurrence. The project has been broken into four areas which follow. Plate 5 in the main report shows a plan view of the nonstructural Plan B.

Area 1 - Roger Williams Company - The project involves the construction of 700 feet of a 6 to 7.5-foot high "I" or "T" wall. The wall would be located on the west side of the complex and inclose 2.25 acres of paved parking and loading area. This would include 2 vehicular stoplog gates 40 feet wide to form a closure in times of flood and to provide passage of traffic during normal times. The north, south and east sides of the structure would be protected by waterproofing measures and the use of temporary flood shields 2.75 feet high. See Plate 5 in main report for details.

Area 2 - Health Tex - The protection of Health Tex will include the construction of 430 feet of a 7.5-foot high "I" or "T" wall. This would be located on the north side of the complex inclosing .65 acres of paved parking and loading area. Two vehicular stoplog gates with 40-foot openings would be provided to form a closure during times of flood. During normal times, complete access would be available. The east, south, and west sides of the building would be protected by waterproofing measures and the use of temporary flood shields 2.75 feet high. See Plate 5 in main report for details.

Area 3 - Okonite Co. - The protection of Okonite Co. will include the construction of 160 feet of a 2-foot high gravity wall with flood shields on the south side of the complex. The rest of the building would be protected by waterproofing measures and the use of 8-inch temporary flood shields. See Plate 5 in main report for details.

Area 4 - Municipal Pumping Station - The pumping station will be protected by a combination of waterproofing and a flood shield.

ESTIMATE OF COSTS

Basis of Estimates - Topographic maps of the US Geological Survey, on a scale of 1:24,000 with 10-foot contours, were supplemented by field survey of the studied dike alignment and adjacent areas. Foundation conditions were determined by field reconnaissance and foundation explorations. Quantities of the principal construction items were estimated on the basis of a preliminary design which would provide safe and adequate structures.

Unit prices are based on current average bid prices for similar construction projects in the Rhode Island area.

Contingencies, Engineering and Overhead - To cover contingencies, construction and relocation costs have been increased by 20

percent. Costs of engineering, design, supervision and administration are estimated lump sums based on knowledge of the project area and experience on similar projects.

First Costs - A detailed breakdown of first costs for the structural project is given in table 4-4. The costs for the nonstructural are shown in tables 4-5 and 4-6.

Annual Charges - The estimate of Federal annual charges is based on interest at 7-3/8 percent of the Federal investment plus the amount required to amortize the investment over the assumed 100-year life of the project. Non-Federal interest and amortization charges were computed in a similar manner at the same interest rate. Non-Federal charges also include amounts for maintenance and operation of the project and interim replacement of equipment having an estimated life of less than 100-years. A summary of the costs is shown in Appendix 7.

TABLE 4-4

PLAN A

FIRST COST - BERKELEY LOCAL PROTECTION PROJECT
FEB 1981 PRICE LEVEL*

Description	Quantity	Unit	Unit Cost	Amount	Total
Lands & Damages					
Land & Improvements	1	Job	LS	95,000	
Temporary Construction Easements	1	Job	LS	7,000	
Severance Damages	1	Job	LS	14,000	
Relocation Assistance	1	Job	LS	1,800	
Acquisition Costs	1	Job	LS	18,000	
Contingencies (20%)	-	-	-	27,160	
				162,960	162,960
Relocations					
Roadways	1	Job	LS	25,000	
Utilities	1	Job	LS	12,500	
Contingencies (20%)	-	-	-	7,500	
Engineering and Design (15%)				6,750	
Supervision and Administration (10%)				4,500	
				56,250	56,250
Levees & Floodwalls					
Site Preparation	1	Job	LS	13,000	
Stream Control	1	Job	LS	13,000	
Levees					
Excavation (Stripping)	15,400	CY	2.00	30,800	
Excavation (Unclassified)	27,000	CY	3.00	81,000	
Excavation (Trench)	13,000	CY	4.00	52,000	
Impervious Fill	89,000	CY	6.50	578,500	
Pervious Fill	15,000	CY	6.00	90,000	
Gravel Bedding	13,000	CY	7.00	91,000	
Crushed Stone	4,700	CY	16.00	75,200	
Stone Slope Protection	18,500	CY	35.00	647,500	
Topsoil	4,000	CY	4.50	18,000	
Seeding	21,000	SY	1.25	26,250	
Road Gravel	1,000	CY	8.50	8,500	
Steel Bin Type Ret. Wall	1	Job	LS	40,000	
Ramp Fill (Martin St.)	2,800	CY	3.50	9,800	
6" Perforated Sub-Drain	4,600	LF	6.00	27,600	
Sub-Drain Manholes	11	EA	900.00	9,900	
				1,786,050	

*Costs are updated in Economics Appendix.

TABLE 4-4 (Cont'd)

Description	Quantity	Unit	Unit Cost	Amount	Total
Floodwalls					
Concrete	1,800	CY	250.00	450,000	
Steel Sheet Pile Cut-off	34,800	SF	15.00	522,000	
				972,000	
Drainage					
Excavation (Trench)	5,800	CY	4.00	23,200	
Storm Drains	3,500	LF	40.00	140,000	
Manholes	9	EA	950.00	8,550	
				171,750	
Sluice Gate & Access Bridge					
Access Bridge	1	Job	LS	2,000	
Sluice Gate	1	Job	LS	13,000	
Concrete	20	CY	270.00	5,400	
				20,400	
Pumping Station					
Excavation	2,040	CY	4.00	8,160	
Reinforced Concrete	588	CY	230.00	135,240	
48" Steel Discharge Pipe	180	LF	130.00	23,400	
Gravity Feed 48" Concrete Pipe	266	LF	135.00	36,180	
Electrical	1	Job	LS	27,000	
Pumps & Mechanical Equip.	1	Job	LS	162,000	
Overhead Crane	1	Job	LS	13,500	
Sluice Gate w/Structure	1	Job	LS	13,500	
Access Bridge	1	Job	LS	3,500	
Dewatering	1	Job	LS	52,000	
Miscellaneous Items	1	Job	LS	30,000	
Gravel Bedding	216	CY	8.00	1,728	
Stone Protection	400	CY	15.00	6,000	
Fill	1,500	CY	3.00	4,500	
				516,708	

TABLE 4-4 (Cont'd)

Description	Quantity	Unit	Unit Cost	Amount	Total
Swing Gates					
Reinforced Concrete	900	CY	220.00	198,000	
4" Concrete Sidewalk	140	SY	12.20	1,700	
3" Bit. Concrete	270	SY	15.00	4,050	
Gravel Base Coarse	410	CY	8.00	3,280	
Compacted Sand Fill	2,340	CY	5.00	11,700	
General Excavation	4,700	CY	4.00	18,800	
Bit. Concrete Excavation	270	SY	2.00	540	
Remove & Replace R.R. Tracks	350	LF	30.00	10,500	
Sewer M.H. Cover 3" Dia.	1	Job	LS	300	
Floodgates 2 (25'x11') Doors	1	Pair	LS	61,000	
Railroad 4 (9.5'x9.5') Doors	2	Pair	LS	40,000	
				349,870	
Ponding Area					
Excavation	1,800	CY	3.00	5,400	
Seeding	5,600	SY	1.25	7,000	
				12,400	
		SUBTOTAL		3,829,178	
Contingencies (20%)	-	-		765,836	
				4,595,014	
Engineering & Design (15%)	-	-		689,252	
Supervision & Administration (10%)	-	-		459,501	
				5,743,767	219,210
		TOTAL PROJECT FIRST COST			5,962,977
				Use	$6,000,000

Note
EA - EACH
SY - SQUARE YARD
CY - CUBIC YARD
LF - LINEAR FOOT
LS - LUMP SUM

TABLE 4-5
Plan B

Preliminary Estimate Real Estate Costs - Berkeley Local Protection Project

	Health-Tex Inc.	The Okonite Co.	Roger Williams Food
1) Permanent Easement	32,000 SF	16,500 SF	32,200 SF
Perm. Ease. Cost	$9,000	$5,000	$9,000
2) Temporary Easement	66,200 SF	35,500 SF	67,600 SF
Temp. Ease. Cost	$3,700	$2,000	$3,800
Contingencies	$2,500	$1,400	$2,000
Acquisition Cost	$4,000	$4,000	$4,000
3) Work area Temp. Contractors	$2,800	$2,800	$2,800
Total REAL ESTATE COST	$22,000	$15,200	$22,200

TOTAL COST: $60,000

1) Permanent easement 10 feet wide at building facades and either side of concrete walls.

2) Temporary easements contiguous to Permanent easements additional 20 feet wide.

3) Contractors work area - a three acre parcel has be allocated at 1 acre per builidng per year use.

TABLE 4-6

PLAN B

FIRST COST - BERKELEY LOCAL PROTECTION PROJECT
June 1981 Price Level

Health Tex Inc

Description	Quantity	Unit	Unit Cost	Amount	Total
Lands & Damages					$22,000
Relocations					0
Waterproofing Walls					
Excavation	1970	LF	5.50	$10,835	
Cleaning Walls & Water proofing	1970	LF	11.00	21,670	
Restoring Site	1970	LF	1.00	1970	
Floodwalls	510	LF	390.00	198,900	
2 Flood Gates w/Stop Logs	1	Job	LS	60,000	
Flood Shields	330	SF	60.00	19,800	
Pump Station	1	Job	LS	20,000	
		Subtotal		333,175	
		Contingencies 20%		66,635	
				399,810	
Engineering & Design 15%				59,972	
Supervision & Administration 10%				39,981	
		Subtotal		$499,763	499,963
		Total First Costs			$521,763

TABLE 4-6 (Cont'd)

PLAN B

FIRST COST - BERKELEY LOCAL PROTECTION PROJECT
JUNE 1981 PRICE LEVEL

OKONITE CO.

Description	Quantity	Unit	Unit Cost	Amount	Total
Lands & Damages					$15,200
Relocations					0
Waterproofing Walls					
Excavation	1,370	LF	5.50	7,535	
Cleaning Walls & Water-proofing	1,370	LF	11.00	15,070	
Restoring Site	1,370	LF	1.00	1,370	
Flood Shields	75.00	SF	60.00	4,500	
Flood Walls	1	Job	LS	3,000	
		Subtotal		31,475	
		Contingencies 20%		6,295	
				37,770	
Engineering & Design 15%				5,666	
Supervision & Administration 10%				3,777	
				$47,213	$47,213
		Total First Cost			$62,413

TABLE 4-6 (Cont'd)

PLAN B

FIRST COSTS - BERKELEY LOCAL PROTECTION PROJECT
JUNE 1981 PRICE LEVEL
ROGER WILLIAMS

Description	Quantity	Unit	Unit Cost	Amount	Total
Land & Damages					$22,000
Relocations					0
Waterproofing Walls					
Excavation	1,240	LF	5.50	6,820	
Cleaning Walls & Water-proofing	1,240	LF	11.00	13,640	
Restoring Site	1,240	LF	1.00	1,240	
Floodwalls	675	LF	390.00	263,250	
Flood gates w/stop logs					
Stop logs	1	Job	LS	36,000	
Excavation/fill	100	CY	6.00	600	
Reinforced Concrete	36	CY	220.00	7,920	
I-Beams	1	Job	LS	2,000	
Asphalt	100	SY	10.00	1,000	
Flood Shields	80	SF	60.00	4,800	
Cantilevered Wall	300	LF	80.00	2,400	
Pump Station	1	Job	LS	40,000	
		Subtotal		401,270	
		Contingencies 20%		80,254	
				481,524	
Engineering & Design 15%				72,229	
Supervision & Administration 10%				48,152	
				601,905	601,905
		Total First Cost			$624,105

TABLE 4-6 (Cont'd)

PLAN B

FIRST COST - BERKELEY LOCAL PROECTION PROJECT
JUNE 1981 PRICE LEVEL

PUMP STATION

Description	Quantity	Unit	Unit Cost	Amount	Total
Lands & Damages					0
Relocations					0
Waterproofing					
Excavation	120	LF	5.50	660	
Cleaning & Waterproofing	120	LF	11.00	1,320	
Restoring Site	120	LF	1.00	120	
Flood Shields	60	SF	60.00	3,600	
		Subtotal		5,700	
		Contingencies 20%		1,140	
				6,840	
E&D 15%				1,026	
S&A 10%				684	
				8,550	8,550
		Total First Cost			$8,550

SUMMARY FIRST COSTS - PLAN B

Building	Cost
Health Tex Incorporated	$ 521,763
Okonite Company	62,413
Roger Williams	624,105
Pump Station	8,550
TOTAL PROJECT FIRST COST	$1,216,831
Use	$1,220,000

APPENDIX 5

RECREATION AND NATURAL RESOURCES

APPENDIX 5

RECREATION AND NATURAL RESOURCES

TABLE OF CONTENTS

NATURAL RESOURCES

The Blackstone River Basin drains approximately 476 square miles, 334 square miles of which are in Massachusetts with the remaining 142 square miles in Rhode Island. The basin is about 46 miles long with an average width of approximately 12 miles. The river originates near Worcester, Massachusetts, and runs in a southeasterly direction to the tidewaters of the Seekonk River in the area of Providence and Pawtucket, Rhode Island.

There are numerous small storage reservoirs in the Blackstone Basin that are used primarily for industrial and municipal water supplies. In addition, many dams were constructed in the 19th century to provide hydropower for industries along the river's banks. These dams, to a minor extent, help control flooding. There is one large reservoir located on the West River in Uxbridge, Massachusetts, which provides flood protection for communities along the West and Blackstone Rivers.

The Blackstone River receives large amounts of treated and raw domestic and industrial sewage. During periods of low water, over 95 percent of the flow in the stream immediately below Worcester includes discharge from the Worcester Wastewater Treatment Plant, untreated raw domestic sewage, and wastewaters from other sources in Worcester. The river water in this reach is characterized by offensive odors, high turbidity, high concentrations of suspended and organic material, high bacterial counts, and low dissolved oxygen (DO) levels. With this initial load of pollutants and with the many other sources of municipal and industrial waste added along its course, the Blackstone River is considered less than Class C quality throughout most of its length. Many of the tributaries are Class A or B at their headwaters, but are Class D or E when they enter the Blackstone.

The basin falls within two major physiographic regions: the New England Upland and the Narragansett Bay Basin. The upland region, which comprises more than two thirds of the area, is moderate in relief with elevations generally near 300 feet, but with maximum elevations of over 1,000 feet. Except for changes resulting from glaciation and stream erosion, the uplands reflect the resistant bedrock. The Narragansett Basin has low hills and plains; generally the elevations are less than 200 feet. Bedrock is of the less resistant sedimentary type.

The Blackstone River Valley in the vicinity of the Berkeley Industrial Park is rather broad and flat with the valley walls rising approximately 200 feet above the flood plain. In this stretch, the river drops uniformly at about 11 feet per mile. Upstream of this area, the river drops approximately 25 feet per mile. The topography has been extensively modified by glaciers.

The general geology of the entire basin consists of various deposits of glacial overburden. Till covers most of the area, but is generally thin on the hills. Water-laid sands and gravels are primarily in the valleys; however, some isolated deposits are scattered at higher elevations. Alluvium is confined primarily to the river channels. Outcrops of bedrock are common. Generally the rocks are a complex of metamorphosed sedimentary and igneous rocks. Included in the igneous group are granites, diorites, greenstone, schist, quartzite and various other abundant types. The sedimentary rocks begin just east of the industrial park and extend in a northerly direction, marking the beginning of the feature known as the Narragansett Basin. A fault is located approximately two miles from the project site, but it is not considered active.

The proposed dike of the Berkeley Local Protection Project would be located primarily on sand and gravel. These deposits are at least 30 feet deep, and are resting upon quartz bedrock. Borings in the area showed ground water about 10 feet below the surface, or approximately at the river's level.

The Blackstone River Basin lies near the northern extremity of the Appalachian Oak Forest. Oak and hickory dominate most of the basin with maple, birch and beech characterizing the adjoining Northern Hardwood Forest around the western and northern edges of the upland. Outside the urban areas, the land is mostly forested but farm and pasture lands are scattered about. The oak-hickory forest land has little current commercial value, except for firewood or house lots. White pine, valued for timber, is present but is rare. The region's extensive and widely scattered upland swamps and marshes contain a great variety of vegetation, and are valued as wildlife habitat as well as natural drainage regulators.

The site where the dike would be located is a fairly large flood plain which is, for the most part, urbanized. Otherwise it is dominated by grass species. However, the riverbank does have small clusters of trees; the primary species are sycamore (Platanus occidentalis), red maple (Acer rubrum), the black and red oak (Quercus velutina and Q. rubra), and gray birch (Betula populifolia). There is one fairly dense stand of trees along the southern side of the industrial park and a backwater area that is often flooded in the early spring. Many of the previous species mentioned are found in this dense stand and backwater area.

RECREATION

The State of Rhode Island has identified the major concerns for recreatin and natural resources of the region. The detailed analysis is found in the Plan for Recreation, Conservation and Open Space, June 1978.

This plan also serves as Rhode Island's Statewide Comprehensive Outdoor Recreation Plan (SCORP).

The following general goals were established to guide the formulation of all plans and implementation programs concerning recreation and natural resources throughout the State:

1. Provide for adequate and diverse recreational opportunities and facilities primarily to meet the needs of the State's residents while also attracting and serving visitors.

2. Preserve and protect open space so as to enhance the total quality of the environment.

3. Insure the sound use and development of appropriate land and water resources in Rhode Island for recreational purposes.

4. Recognize that Narragansett Bay is the State's most important natural feature and recreational resource.

5. Improve the capability of both public and private sectors to respond to recreational needs at both the community and regional levels within the State.

6. Utilize, to the greatest extent possible, the capabilities of the private sector in the outdoor recreational area.

7. Improve opportunities for water-oriented recreation by reducing pollution and controlling water quality in Rhode Island's water bodies.

A number of key recommendations were formulated to help meet these established goals. Those following are the most pertinent in regard to the Blackstone River Basin:

- Improve use opportunities at existing urban and metropolitan parks and develop additional neighborhood recreation areas.

- Improve public transportation to recreation sites particularly in and around urban areas.

- Provide freshwater swimming principally in the west and east metropolitan regions, not only to meet supply deficiencies but also as a substitute for saltwater swimming.

- Adopt a formal arrangement between the Rhode Island Historical Preservation Commission and the Department of Environmental Management for the purpose of facilitating the orderly development of areas that have both historic and recreational significance.

- Complete a feasibility study for the establishment of a scenic and recreational river system in the State.

- Meet picnicking deficiencies in all regions, and particularly the west metropolitan and northeast regions.

- Meet Statewide supply deficiencies in tennis. These are most acute in the west metropolitan and northeast regions.

- Activity in many recreation pursuits should be stimulated by Government through the provision of accessible facilities and through the promotion of those recreational pursuits that exhibit multiseason durability.

- The Statewide Planning Program should complete it flood plain management study and examine alternative protection and regulation techniques for flood prone areas.

- Investigate legal provisions which create conflicts between private ownership and the recreational use of the State's navigable waterways. Clarify public regulations for recreational use of navigable waterways.

- Identify, publicize, and protect areas of scenic, historical, and cultural interest for the large sightseeing population.

- For the promotion of environmental awareness, encourage the Department of Education to foster the use and study of appropriate natural areas as part of the educational curriculum in all school districts.

In order to assess regional recreation and natural resource problems and needs, the State used a number of different survey techniques. Various questionnaires and phone calls were utilized in order to compile and understand the recreation needs and concerns of the State. These surveys yielded a number of general conclusions which form a framework for future recreation planning. Numerous activities were surveyed, with the five most popular by order of popularity being: saltwater swimming, freshwater swimming, sightseeing, picnicking and outdoor games.

The surveys also provided valuable information on the supply and demand for recreation facilities. It was discovered that people in general will travel to the closest available supply implying that there is overcrowding of facilities in and around population centers. Also, people tend to travel shorter distances and participate more if supply is close at hand. Surveys and models have shown that supply of recreation facilities is distributed unevenly in relation to the demand. With the exception of tennis and picnicking it was revealed that there is a surplus of supply on a Statewide basis for the most popular activities. However, demand is often

affected by location of supply, quality of facilities and fees charged.

In specific regard to the Berkeley Local Protection Project, the proposed structural alternative essentially consists of a 5,100$\pm$ foot earthfill dike and concrete wall varying from 10 to 20 feet high along the east bank of the Blackstone River in Cumberland, Rhode Island. The only recreation facilities existing in the area to be immediately affected by the dike are two ball fields between Martin Street and Health Tex, Inc. The ball fields, one baseball and one softball, are on town owned land between the town of Cumberland water supply pumping station and one of the two access roads to Health Tex from Martin Street. The Berkeley Local Protection dike would be located between this access road and the Blackstone River. The present plan for the dike includes a relocated access road from Martin Street to Health Tex, which would pass through the softball field.

Both of these municipal ball fields are used on a regular basis by residents of Berkeley and are the only facilities of their kind in the area. Both are fairly well maintained, but could be improved, if desired, by the addition of bleachers and possibly a few picnic tables under the trees along Martin Street. Since construction of the proposed relocated access road would eliminate the softball field, thereby having a significant adverse impact on this important recreation facility, it is recommended that as further engineering and design takes place that consideratin be given to eliminating the proposed access road and instead improving the other access road to Health Tex from Martin Street. This would avoid any direct impact on the ball fields as well as to eliminate most of the heavy truck traffic next to the ball fields along Martin Street and the access road by the proposed dike. The other access road to Health Tex is also shorter and more direct. It is also recommended that the size of the ponding area near the dike and Martin Street be minimized and located as far as possible from the ball fields to avoid any additional conflict with recreational use in this area. These measures will preserve and protect the valuable recreation opportunities afforded the public in this highly urbanized and industrialized area.

No further recreational development is planned in connection with this project due to the very limited nature of the resource. No additional cost for recreation facilities will therefore be incurred. There will also be no cost sharing requirements or further administrative responsibilities in addition to those already necessary to maintain the ball fields at the present time.

FISH AND WILDLIFE

In 1975, the Rhode Island Division of Fish and Wildlife sampled the fish population and water chemistry in the vicinity of the Berkeley Industrial Park. They found the fish population to consist of the following: goldfish (Carrassius auratus), common sunfish (Leonis sp.), brown bullhead (Ictalaus nebulosus) and white suckers (Catostomus commersonnic). These species are tolerant to adverse conditions, which spot sampling of the water chemistry indicates to be prevalent.

Dissolved oxygen is extremely important to aquatic organisms. Only the hardiest fish are able to survive with 5.5 parts per million (ppm) of DO which has been measured in the Blackstone River, while species such as trout require at least 7.0 ppm. Consequently, this river in the vicinity of the Berkeley Industrial Park is not an ideal environment for most game fish. However, with future reduction of pollution the potential for restoration of a freshwater fishery could be realized with largemouth bass, chain pickerel and possible northern pike being the principal game fish. The present value of the fishery is low due to the pollution in the Blackstone River.

There is limited habitat in the vicinity of the proposed dike for wildlife. Some of the species that may be found in the project area include pheasant, woodcock, cottontail rabbit, woodchuck and a variety of songbirds. There are no known rare or endangered species within the area of the proposed project. Following is the Conservation and Development Report of the US Fish and Wildlife Service dated 22 September 1977 for the Blackstone River at Berkeley, Rhode Island.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Division of Ecological Services
P. O. Box 1518
Concord, New Hampshire 03301

BLACKSTONE RIVER AT BERKLEY, RHODE ISLAND

Conservation and Development Report of the U.S. Fish and Wildlife Service, on a study for urban flood control, floodplain management, water supply, and recreation of the New England Division, U.S. Army Corps of Engineers.

The study was authorized by a resolution of the Senate Committee on Public Works adopted 29 May 1968, under Section 3 of the Rivers and Harbors Act. This report is prepared under authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.), in cooperation with the Rhode Island Division of Fisheries and Wildlife. A Preliminary Report on the Narragansett Bay and Pawcatuck Drainage Areas was issued by this Service on October 29, 1968.

The local flood protection project at Berkley provides for the construction of earth dikes and concrete floodwalls along the left bank of the Blackstone River in Cumberland, Providence County, Rhode Island. The project would extend from river station 280+00 (approximately 2 miles above Valley Falls Pond) to river station 320+00; a distance of about 4,000 feet. The plan of protection would provide for construction of 3,800 feet of earth dikes, 1,450 feet of concrete floodwall, a pumping station, a vehicular ramp over the dike at Martin Street, a vehicular gate, two railroad stoplog structures, interior drainage, and other appurtenant works. The project would provide protection for the 40-acre industrial park located on the east bank of the Blackstone River. The dikes in general would have a top width of 10 feet and slopes of 2.5 on 1 both landside and riverside. Slope protection will consist of 15 inches of protection stone on 12 inches of gravel bedding on the riverside and 6 inches of seeded topsoil on the landside. The dike will be 16 feet high and 3,800 feet long.

The floodwall will be an I-type floodwall with sheet piling cut-off for seepage control. The height of the wall along the river's edge would be approximately 16 feet. The 1,450 feet of concrete I-type concrete floodwall would be constructed along the river face of the existing 42-inch sanitary sewer main with transition changes at each end to earth dikes.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

A pumping station, for discharge of interior drainage, seepage, and industrial wastewater will be located at the downstream side of the Martin Street Bridge.

The area of the proposed dike consists of industrially-zoned land located along and adjacent to the Blackstone River. The 40-acre tract to be protected is primarily devoted to industrial buildings, roadways, and parking lots. Those areas not occupied by the various industries and commercial operations consists of open fields having a cover of grass. Riparian vegetation, approximately 8 acres, is primarily native grasses with a sparse fringe of oak, sycamore, and birch trees with blackberries and shrubs interspersed. An area at the rear of the Health-Tex building is occupied by a thick cover of birch, blackberries, and native grasses.

While not overly significant this riparian vegetation does provide habitat for wildlife within an urban-industrial setting. Wildlife species such as pheasant, woodcock, cottontail rabbit, woodchuck, and a variety of songbirds may be found within the project area.

The Blackstone River currently supports a warmwater fish population which has a low recreational value due to pollution. Principal fish species in the project vicinity include goldfish, white suckers, and common sunfish. With pollution reduction and restoration of freshwater fisheries potential, the lower Blackstone could support a warmwater fishery based upon largemouth bass, chain pickerel, and possibly northern pike. With extensive access and a return of alewife and possibly shad, the lower river fishery could be expanded many fold.

The project is not expected to have a significant impact upon fishery resources. However, construction of the flood protection dike and I-walls will destroy approximately 8 acres of riparian wildlife habitat.

In summary, the project, as planned, affords no outstanding benefits to fish or wildlife. In general, due to the urban character of the area and the low fishery values because of pollution, the project will have no severe adverse impact upon fish and wildlife resources. Commitments of fish and wildlife resources are limited to the loss of streambank vegetation and associated wildlife displaced by the dike and floodwall structures.

No feasible method for direct prevention of the anticipated loss of riparian habitat appears possible without altering the planned design and operation of the project. However, possibilities for mitigation of some losses are evident. Planting the landside face of the dike with vegetative species valuable to wildlife would be effective in mitigating anticipated damages. Ground cover plants of value to wildlife of the area would be white clove and reed canary grass, or a commercial forage mixture containing red clover, alsike clover, timothy and red top known to seed outlets as "Forage Mixture 1 and 2." Desirable shrubs for the area would be autumn olive or fragrant sumac. Assuming public access is assured,

this measure will provide an area for bird watchers, wildlife photographers, naturalists, and school children with an opportunity to observe wildlife without requiring extensive travel.

In the future, with pollution reduction, the quality of water within the Blackstone River will be improved to meet the biological requirements of fish native to the Blackstone Basin. With revival of this fishing opportunity, fishermen from Berkley, Cumberland, and the Blackstone Basin, as a whole, will be in need of streambank access.

There is opportunity, in connection with the construction of the dike and floodwall which parallels the river, to contribute to development and utilization of future fishery resources. Provision of public access and use of the project rights-of-way, and modification of the project and improvement to include a canoe and cartop boat launching facility would insure maximum project benefits.

Average annual fisherman use would be approximately 3,800 fisherman days with an average annual equivalent value of $3,700.

We estimate that the parking space required for those actually fishing at peak periods will require 1.0 acre of area in order to accommodate bank and boat fishermen. It may be possible through use agreements to utilize existing parking space provided by industries within the industrial park.

Benefits from the proposed fishermen access would not be realized until pollution reduction is achieved and fisheries management programs are implemented. In the interim, canoests and others who desire to float the river will benefit from the access and launching facility.

Therefore, the U.S. Fish and Wildlife Service recommends that:

(1) Public access and use of project rights-of-way along the Blackstone River, except areas reserved for reasons of safety of the public or project operation, be provided.

(2) The landside face of the dike be planted with vegetative species valuable to wildlife.

(3) At least one canoe and cartop boat launching facility and parking area be provided.

We do not plan to make additional studies of this project nor prepare any additional reports unless the project plan involves improvements and methods different from those described above.

Date signed: September 22, 1977

Fred Benson

Gordon E. Beckett

Fred Benson
Project Manager

Gordon E. Beckett
Supervisor

APPENDIX 6

SOCIAL AND CULTURAL RESOURCES

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SOCIAL WELL-BEING COMPONENTS

INTRODUCTION

The other social effects account includes project effects traditionally termed intangible. According to the Water Resources Council's Principles and Standards, a project's effect on social well-being is best described in terms of its effects on health, safety, and community well-being, effects on educational, cultural, and recreational opportunities, and some indication of the probability a project would cause community disruption or injurious displacement of people.

Reducing the risk of flooding in the Blackstone River Basin has been the major objective throughout the progress of this study. Many alternatives were dropped from consideration when their contribution to this objective was not sufficient to warrant further study. Because few alternatives met the planning objective, as well as planning constraints, only one problem area remains which is feasible for additional study. This area is the Berkeley project area in Cumberland, Rhode Island, covering approximately 70 acres occupied by the Berkeley Industrial Park, a town of Cumberland Pumping Station, and a recreational playing field. Since this is the only area receiving consideration for flood control measures, other isolated locations within the river basin would still face flooding threats. While wetland protection laws, flood plain zoning, and the National Flood Insurance Program would constrain development in the flood plain, new development within the drainage basin could increase the flood risk in some of these areas. Future losses without a project have been estimated and are displayed in Table 6-1 and presented in Appendix 7 in greater detail.

THE BERKELEY PROJECT AREA

As provided in Appendix 4, there are two alternatives that are being considered for flood protection for the Berkeley project area. These alternatives include one structural alternative and one nonstructural alternative which are compared to the without project condition to derive the impacts specific to each alternative.

Project impacts in the context of the other social effects account can be classified as beneficial or adverse in their contribution to the national objectives, short or long term in their duration, construction or post-construction related depending on their timing. Some effects can have both a beneficial and adverse dimension which often depends on an individual's perception.

The Berkeley project area consists of 70 acres along the Blackstone River in Cumberland, Rhode Island. This area is occupied by three industrial establishments of the Berkeley Industrial Park: Roger Williams Foods, Health Tex, Incorporated, and the Okonite Company which are subject to substantial flood damage. Some of these establishments have

TABLE 6-1

EXPECTED ANNUAL LOSSES ON MAINSTEM
(June 1979 Price Level)

City or Town	Rural	Urban*	Industrial	EXISTING CONDITIONS LAND USE Railroad	Highway	Utility	Total
Primary Impact Area	$ 930	$275,900	$930,620	$38,440	$77,655	$5,735	$1,329,280
Blackstone		155		8,060	13,795		22,010
Millville		2,015	379,905		465		382,385
Uxbridge	310		4,340		4,650		9,300
Northbridge		20,305	21,700		15,500		57,505
Sutton	155	155	14,880		6,510		21,700
Pawtucket		79,825	59,675		5,270	4,030	148,800
Central Falls		61,535	115,785	19,685			177,320
Cumberland	465	107,725	296,930	10,695	31,465	1,705	458,025
Lincoln		4,185	37,355				52,235
Other Areas	1,705	4,960	51,150	27,900	63,705		149,420
Millbury	155	1,860	29,450	27,435	26,505		85,405
Grafton	1,550	3,100	21,700	465	37,200		64,015
Total Blackstone Watershed	$2,635	$280,860	$981,770	$66,340	$141,360	$5,735	$1,478,700
Share	0.2	19.0	66.4	4.5	9.5	0.4	100.0%

*Urban: Residential and Commercial

Source: "Water Resource Development Study, Blackstone Watershed, Massachusetts and Rhode Island - Economic Studie C. E. Maguire, Inc. 1974. Updated by Corps of Engineers - 1979

expanded their facilities as recently as the early 1970's and account for a considerable portion of the manufacturing employment in Cumberland.

Berkeley Oval Park containing a town-owned baseball field and a softball field lies between Martin Street and Health Tex, Incorporated within the immediate project impact area. This recreational facility fills an important role in a growing community of limited recreational resources. Adjacent to this site is a Municipal Water Works Pumping Station.

There are several acres of vacant or underused land withing the industrial park for which development requests have been turned down by the Rhode Island Department of Natural Resources since the land is lacking flood protection.

Cumberland is under the regular phase of the National Flood Insurance Program (NFIP) within the Federal Emergency Management Agency (FEMA). Acceptance into the regular phase indicates that Cumberland has established flood plain zoning laws which restrict development in flood plain areas, including this one in Berkeley.

SPECIAL CONSIDERATIONS

In addition to the industrial establishments needing flood protection, there are other facilities located within this area that are of particular concern because of the existing flood risk. These include the Blackstone Valley Sewer Interceptor, the Providence and Worcester Railroad, and the Cumberland Water Works.

A 42-inch trunk sewerline extending from Lonsdale to Woonsocket was completed in 1970. The line has interceptors at Ashton serving Lincoln and Smithfield and another at Valley Falls which serves all of Cumberland below Interstate 295. Most of the pipeline was laid along the riverbanks and is almost entirely in the flood plain. As part of construction specifications, precautions were taken to protect this line from infiltration and breakage, but a flood greater than a 100-year event would probably damage the line.

The Blackstone Valley Chamber of Commerce has expressed particular concern over the sewerline and has indicated that a broken or destroyed sewerline could cause 40 industries tied into the system to close down. Damage to the sewerline could result in the spreading of raw sewage over the flood plain downstream.

Correspondence between the Corps and the Providence and Worcester Railroad Company during the progress of this study emphasizes the great concern over the threat of flooding to the existence of the railroad. The correspondence suggested that without a flood control plan for the railroad, a flood would hurt the economy of two large cities, namely, Worcester, Massachusetts, and Providence, Rhode Island, and would be

devastating to the Blackstone Valley and the railroad itself. The time it would take the railroad to recover from a major overflow of the Blackstone would be astronomical, leaving the customers in the Blackstone area without freight for a long period of time. Companies in the Berkeley area, including Owens-Corning Fiberglas , Roger Williams Foods, Okonite Company, and Peterson/Puritan, Incorporated, would lose approximately 40 cars of freight on the average of a 6-day period. This does not take into consideration the companies that would lose freight above and below the Blackstone area. Loss of raw material supplies to certain industrial establishments for an extended period of time may cause facilities to shut down and result in lost wages to employees. Although protection in the Berkeley area would not reduce the risk of track washout north and south, it would reduce overall damages.

The Cumberland Water Works maintains a water supply well which is located on the property next to the recreational field. During a flood event the pumping station may shut down resulting in an overall decrease of water supply for Cumberland for the period until pumping could be restored. There is a possibility also that floodwaters could contaminate the water supply.

THE STRUCTURAL ALTERNATIVE

Effects on Health, Safety, and Community Well-Being

The major objective, reducing flood risk in this industrial area, would be met by the construction of dikes and walls. The project, however, would raise the flood stage upstream and increase damages experienced by the Owens-Corning Fiberglass plant and further endanger the single resident opposite the plant. During the advance engineering and design phase these damages would be alleviated or mitigated.

The project would protect the three industrial establishments, which are subject to substantial flood damage, and would protect employee wages that would be lost with a plant shutdown during a flood event.

The earthen dike would protect from washout the existing Blackstone Valley Sewer Interceptor, which is on the edge of the river and partially above grade within its own protective embankment. The dike would also permit safe operation of the Cumberland well water supply during standard project flood conditions.

Dike placement would prevent the inundation of a section of the Providence and Worcester Railroad tracks within the limits of this project. Railroad operations during major floods would still be restricted due to inundation of rail sections at various upstream and downstream locations.

The primary neighborhood impact would result from truck travel along the access route between the site and the source of material for

construction. The most likely access route would follow a mile-long segment of Mendon Road through residential areas north of the project site to Route 1 or Route 95. In addition to generating high noise levels, slow moving trucks would interfere with traffic flow. The construction activities would raise the levels of air, noise, and dust pollution. However, these impacts are temporary and would prevail only during the construction period.

Effects on Educational, Cultural, and Recreational Opportunities

Construction activities involved with the Berkeley Local Protection Project would negatively impact the Berkeley Oval Park. During Construction, there would be measurable disruption to the park area, since it is immediately adjacent to both the proposed dikes and to the major access road, Martin Street. Heavy equipment and truck operations required for construction of the 4,000-foot dike would generate dust, diesel fumes, and high noise levels. It is possible that the park would be unusable during the construction period and could be taken in temporary easement for movement and storage of construction materials and equipment.

The relocation of the access road to Health Tex, Incorporated from Martin Street would permanently remove a corner of the park from recreational use. Relocation of the access road to another location may be investigated when the study proceeds to Phase I, General Design Memorandum. While the project would provide flood protection to the remainder of the park, it might also lead to pressure to develop this parcel for industrial use, since without the flood threat, its attractiveness for other uses would be enhanced.

Since no social and cultural facilities (churches, clubs, etc.) are located in the immediate vicinity of the proposed project, no such facilities would be directly affected. Since the proposed actions would induce few land changes or alter demographic trends, the project would have no significant impacts on either the social characteristics of the resident population or its demand for social and cultural facilities.

Effects on Community Growth/Future Land Use Development

With implementation of the Berkeley project, several vacant acres lying in the area would probably undergo industrial development. It is highly probable that this development would be realized since local interest in industrial development is pronounced and the area is both sewered and planned for nearly full industrial development. New development would bring additional jobs as well as increased traffic into this area.

The upstream limits of the dike would extend onto property that would possibly be used by the Owens-Corning plant for expansion. Although Owens-Corning has no immediate plans for expansion, past additions have left this the last direction in which to expand. The presence of the dike would negate development in this area.

THE NONSTRUCTURAL ALTERNATIVE

Effects on Health, Safety, and Community Well-Being

The nonstructural measures utilized in this alternative include waterproofing, small walls, and warning. Roger Williams Foods, Health Tex, Incorporated, the Okonite Company, and the town pumping station would be waterproofed. Walls, approximately 6 to 7 feet would be placed around the loading dock areas of Roger Williams Foods and Health Tex, Incorporated. Although no direct losses would be experienced from damages to buildings or contents during a 100-year event, indirect losses would include lost business and wages. The sewer interceptor and the railroad tracks would not receive protection.

Although this alternative considers nonstructural or nontraditional measures, it involves structural activities. The effects of wall construction would be similar to the effects of construction of the local protection project, including increased dust, diesel fumes, and noise levels, and some increase in heavy truck traffic on local roads.

Effects on Educational, Cultural and Recreational Opportunities

No protection would be provided for the Berkeley Oval Park under this alternative. However, placement of walls around the Health Tex, Incorporated loading area, which lies adjacent to the park, would have some temporary effects.

Effects on Community Growth/Future Land Use Development

The nonstructural alternative would not provide protection for the vacant land lying in the industrial park. Vacant land falls under the flood plain zoning regulation as established by Cumberland as part of its acceptance into the regular phase of the National Flood Insurance Program.

A brief comparison of the structural and nonstructural plans shows that Plan A provides a higher level of protection than Plan B. (Plan A provides protection against the SPF event; Plan B provides protection against a 100-year event.) Plan A provides more extensive protection. Plan A not only protects the three industrial establishments, Roger Williams Foods, Health Tex, Incorporated, and the Okonite Company, and the Cumberland pumping station that would be protected in Plan B, but it also protects the Berkeley Oval Park, the Providence and Worcester Railroad, and the Sewer Interceptor. Although Plan B does reduce the structural damages, employees would still be unable to reach the plant during a flood event. However, depending upon dike alignment, Plan A may take away some of the recreational area, whereas Plan B would leave the park undisturbed. Plan A would, though protecting vacant land in the industrial park, and eliminating the 100-year flood plain, make the vacant acreage available for development. Plan B, however, would protect only

flooding. Plan B is implementable in about half the time as Plan A. Another drawback to Plan A is that it increases the flood risk upstream at the Owens-Corning plant.

CULTURAL RESOURCES

Correspondence with the Rhode Island Historical Preservation Commission indicates that the only significant cultural resource which may be affected by the flood dike alternative of this project is the Blackstone Canal, which is listed on the National Register of Historic Places.

The Blackstone Canal was built in 1828 and operated until 1867. Though portions of it have been obliterated in urbanized areas, considerable stretches remain along rural portions of the river in southern Massachusetts and Rhode Island.

The canal segment near the proposed project area is on the west bank of the river, in the town of Lincoln, Rhode Island. It extends from the remains of a cut stone lock basin of the Ashton Dam to another lock site with a modern concrete overflow structure approximately 7,000 feet downstream. The canal towpath is between the canal and river, and consists of an earthbank reinforced in some places with dry laid fieldstone retaining walls. The canal is usually kept full of water, but floods have breached the towpath several times in the past. This occurred most recently during January 1979, when a section of towpath washed out below the Martin Street Bridge, draining the canal. Several areas above the bridge were also weakened at that time. The breach is now patched and the canal has refilled.

The Preservation Commission has requested a study of the potential for dikes on the east bank of the river increasing erosion of the towpath during flood stages. If the flood dike alternative proceeds to further design phases, the possibility of such erosion will be analyzed further. The nonstructural and without condition alternatives, by their nature, are expected to have no effect upon significant cultural resources.

APPENDIX 7

ECONOMICS

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APPENDIX 7 - ECONOMICS

INTRODUCTION

This appendix contains the details of the costs and benefits of the proposed alternatives with an explanatory rational.

The primary purpose of an economic analysis is to provide tangible economic justification of proposed improvements. A project's degree of justification can be determined by comparing the equivalent annual charges of the project's costs with an estimate of equivalent average annual benefits that would be realized over the life of the project.

Project costs and benefits are referenced to a common time basis. The value given to benefits and cost at their time of accrual are made comparable, timewise, by conversion to an equivalent time using an appropriate interest rate. The current approved interest rate applicable to public projects is 7-3/8 percent.

Flood control projects investigated afford varying degrees of protection; therefore, the physical lives also vary from 20 to 100 years. Operation and maintenance costs are incurred each year.

Standard Corps of Engineers procedures were used to develop costs and benefits. Costs include estimates of the value of all goods and services used to construct, operate and maintain a project. Benefits involve estimates of flood damages prevented and other values created. The primary benefit is the reduction of flood damages, which a project accomplishes by protecting homes, businesses and other establishments in the flood plain.

Appendix 7 consists of two major parts. First the entire length of the Blackstone River was examined with particular attention paid to flood prone areas. Plans of protection for these areas were evaluated on the basis of innundation reduction benefits versus project cost. A benefit-to-cost ratio near or greater than one was required for further investigation. Part two consists of an in-depth economic analysis of the only site to display a positive benefit-to-cost ratio, the Berkeley Industrial Park. In addition to estimating the innundation reduction benefit for the structural plan, a complete benefi_ analysis was performed for non-structural flood control measures.

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EXTENT AND CHARACTER OF FLOODING

Experienced 1955

The flood of record for the Blackstone River is the August 1955 flood which caused damage along most of the river's course. Peak discharges that were nearly twice the magnitude of (any) others experienced on the river were produced during this storm. The flood resulted from record rainfall accompanying hurricane "Diane" falling on ground previously saturated by the precipitation of hurricane "Connie," which had occurred only one week earlier. At Uxbridge, Mass., the 1955 flood washed out the Rice City Pond Dam, damaged a woolen mill and caused highway washouts. In Cumberland, Rhode Island, industrial and urban (commercial and residential) losses were inflicted. The flood losses in Lincoln, Rhode Island were largely in the industrial sector. The Lonsdale area (in both Cumberland and Lincoln) was subjected to severe industrial and commercial destruction. Through Central Falls and Pawtucket, flood damage was most pronounced on the right bank of the Blackstone. The commercial area of Pawtucket in the vicinity of Roosevelt and Main Street was the primary damage site while Central Falls experienced mixed urban and industrial losses.

Damage Surveys

NED damage analysts conducted field surveys following the August 1955 flood. The surveys consisted of the appraisal of dollar damages to lands and structures in the form of losses by stage in feet referenced to the record flood crests from hurricane "Diane." Damage appraisal was assisted by the cooperation of local officials and property owners and/or managers who pointed out highwater marks and provided estimates of experienced dollar damages. An additional damage survey was conducted in 1963 and updated in 1975 to account for flood plain development. A final field survey check was accomplished in 1979 to determine final interim changes in potential damages that would result from any altered utilization of the lands within the flood plain. Information gathered in the flood damage surveys provides the stage (elevation) at which damage begins for each property as the lower limit and an estimate of potential damage three feet above the flood crest of record (1955) as the upper limit. Damage estimates are also made for the intermediate stages, in one foot increments, between these limits. This results in an array of potential damages for each stage from ten feet below to three feet above the 1955 flood.

Damage Zones

The damage zones are delineated utilizing hydrologic data developed at specific index stations on the Blackstone River. These index stations effectively partition the river into zones which share

hydrologic characterisitics. The stretch of river which constitutes anyone of these zones is then considered together with the land area along its banks. Delineation of the '55 flooding is utilized to circumscribe the land area belonging to a given one. Designation of the damage zone by hydrologic zone number (previously assigned), index station name, and a definite description completes the process. Table 7-1 of this Appendix shows the zones in question.

Recurring Losses

Recurring losses are those potential damages which are expected to occur at various flood stages under present-day development. Experienced losses, are those which actually occurred during the 1955 event. Factors, in addition to flood plain development, which make recurring losses unique are; riverbed change, local improvement projects, and upstream storage reservoirs. Flood loss information in this study was aggregated into six land use categories; rural, urban (residential and commercial), industrial, railroad, highway and utility. The damage survey evaluated physical damages to structures, contents and machinery and stock as well as non-physical losses such as cost of temporary shelter and subsistence and the uncoverable loss of business revenue and wages. Table 7-2 exhibits recurring losses, by damage zone, for the basin study area, at the present day level of development at the June 1981 price level.

Potential recurring losses were not enumerated for Zones 0, 1, 2, 3 and 8, due to the implementation of the Worcester diversion project. Completed and put into operation in 1960, this facility insures that flood damages in the above five zones in Worcester will be greatly reduced or eliminated.

Damages also were not analyzed in Zone 8 (Blackstone, Mass., and North Smithfield and Upper Woonsocket, Rhode Island) for the following reasons. There appears to be no significant damage potential remaining in the Blackstone and North Smithfield because the profile of the recurring 1955 flood has been lowered through this reach by as much as 10 feet due to channel improvements and operation of the West Hill Dam (completed 1961). The Upper Woonsocket Local Protection Project, completed in 1959, virtually eliminates recurring damages in Woonsocket upstream of the former Hamlet Dam Index Station (Sta. 699 + 00). The lower Woonsocket Local Protection works, completed in 1966, almost entirely eliminates the possibility that the river will overrun its banks in the Woonsocket area of Zone 9. Damage figures for Zone 9 reflect those that will be incurred in Cumberland and Lincoln, Rhode Island.

Reference to Table 7-2 reveals that a recurrence of the 1955 event under present-day development conditions would result in total recurring losses of roughly $50,398,700 (June 1981 dollars).

TABLE 14

INDEX STATIONS - DAMAGE ZONE LIMITS

ZONE	STATE	RIVER	ZONE EXTENT	INDEX STATION	ACTUAL 1955 FLOOD CREST	RECURRING 1955 FLOOD CREST
0	Mass.	Kettle Brook	Stoneville Pond Dam to Worcester Diversion Structure (Sta. 2805+00 to 2742+40)	Worcester Diversion Structure (Sta. 2742+40)	na	490.0
I	Mass.	Kettle Brook	Worcester Diversion Structure to Curtis Pond Dam (Sta. 2742+40 to 2598+00)	Worcester Gaging Station (Sta. 2661+60)	485.6	478.0
II	Mass.	Middle River	Curtis Pond Dam to the former Middle River Bridge, Worcester *** (Sta.2598+00 to 2525+00)	Former location of M.J. Whithall Assoc. Dam (Sta. 2535+00)	458.0	450.8
III	Mass.	Blackstone River	Middle River Bridge to Mouth of Hull Brook* (Sta. 2515+00 to 2331+50)	Worcester-Millbury Town Line (Sta. 2366+50)	416.0	413.4
IV	Mass.	Blackstone River	Mouth of Hull Brook to Millbury Woolen Mills Dam (Sta. 2331+50 to 2196+50)	Former location of Millbury Woolen Mills Dam (Hayward Schuster Dam) (Sta. 2196+80)	364.5	367.3
V	Mass.	Blackstone River	Millbury Woolen Mills Dam to Saundersville Dam (Sta. 2196+50 to 2043+50)	Saundersville Dam (Damaged) (Sta. 2043+50)	312.2	316.0
VI	Mass.	Blackstone River	Saundersville Dam to Mendon St. Bridge, Uxbridge (Sta. 2043+50 to 1357+00)	Former location of Paul Whitin Dam (Sta. 1775+00)	274.0	276.2
VII	Mass.	Blackstone River	Mendon St. Bridge, Uxbridge to Blackstone Manufacturing Co. Dam** (Sta. 1357+00 to 933+00)	Blackstone Mfg. Co. Dam (Tupper Corp. Dam) (Sta. 933+00)	201.7	200.5
VIII	Mass-R.I.	Blackstone River	Blackstone Mfg. Co. Dam to Hamlet Dam Woonsocket (Sta. 933+00 to 699+00)	Former location of Hamlet Dam (Sta. 699+00)	130.5	125.8
IX	R.I.	Blackstone River	Hamlet Dam to Valley Falls Dam, Valley Falls (Sta. 699+00 to 106+00)	Valley Falls Dam (Sayles Finishing Co. Dam) (Sta. 106+00)	61.6	62.5
X	R.I.	Blackstone River	Valley Falls Dam to Slater Mill Dam, Pawtucket (Sta. 106+00 to 4+00)	Old Slater Mill Dam, Pawtucket (Sta. 4+00)	33.5	35.1

* Downstream end of the Worcester Diversion Channel.
** Known as the Blackstone Mill of the Lonsdale Co. (Tupper Dam).
***Known as the McKeon Road Bridge
na Not Available

Table 7-3 shows that nearly one-half of the total losses (45.6%) would occur in the industrial sector. Geographically zones 4, 6 and 9 would sustain the greatest losses, collectively accounting for 70 percent of total recurring damages.

TABLE 7-2

Blackstone River Study Area
Total Recurring Losses, June 1981 Price Level
Referenced to 1955 Flood Crest
Present-Day Development Conditions

Damage Zone	Total Recurring Damages	Percent of Total Losses
Zone 4	$10,867,800	22%
Zone 5	4,761,800	9
Zone 6	10,657,000	21
Zone 7	5,159,700	10
Zone 9	13,391,600	27
Zone 10	5,560,800	11
TOTAL	$50,398,700	100%

TABLE 7-3

Blackstone River Study Area
Percentage Breakdown of Recurring
Losses by Damage Category

	Zone 4	Zone 5	Zone 6	Zone 7	Zone 9	Zone 10	Total
Rural	0.4%	0.6%	2.1%	0	0	0	0.6%
Urban*	2.1	1.8	24.8	1.5	29.4	56.6	20
Industrial	33.8	44.1	36.9	82.5	51.6	37.9	45.6
Railroad	55.1	0.7	0.8	5.6	9.2	0	15.1
Highway	8.5	52.7	35.4	10.4	9.3	3.7	18.3
Utility	0	0	0	0	0.5	1.8	0.3

*includes commercial and residential

As stated in the appendix on Formulation, six areas were studied as potential sites for corrective structural flood control measures. These project areas are; (1) Nipmuc Reservoir and Dam, (2) Uxbridge Local Protection, (3) Modification of Sayles Finishing Co. (Saylesville) Dam, (4) Modification of Old Slater Mill Dam, (5) Ashton Local Protection, and (6) Berkeley Local Protection. In addition, a seventh study was undertaken to determine losses to the railroad system in the basin study area due to its

proximity to the river bank for several miles. The economic analysis to follow provides a brief description of each project to include location, recurring losses, annual losses, annual benefits, annual project costs and the benefit-to-cost ratio. Those projects lacking economic feasibility are reported at the June 1979 price level. The economically feasible Berkeley plans have been updated to June 1981 prices.

Nipmuc Dam and Reservoir

The Nipmuc Dam and Reservoir would be a multi-purpose reservoir with both flood control and water supply functions. Located in Burrillville, Rhode Island, about a mile north of the village of Graniteville, the overall dam height would be 90 feet with five feet allocated to flood control purposes. The dam, reservoir, and buffer zone would require the acquisition of approximately 1,200 acres. The reservoir would have the effect of lowering stages along the Branch and Nipmuc Rivers (Zone 13) in Burrillville and the Blackstone River (Zones 9 and 10) in Cumberland and Pawtucket, Rhode Island. Recurring losses at the 1955 flood crest elevation in the project area amount to approximately $27,391,500 and are distributed geographically as follows:

Zone	Recurring Losses (June 1979 Price Level)	Percent of Total Losses
13	$ 357,000	1.3%
9	22,582,300	82.4
10	4,452,200	16.3

The combination of stage-damage data with hydrologic stage frequency data for each of the three zones gives values for annual losses, annual benefits and residual losses. Annual benfits are determined by comparing annual losses under the "without project" vs. the "with project" condition.

Zone	Annual Losses	Annual Benefits	Residual Losses
13	146,700	72,400	74,300
9	869,600	160,100	709,500
10	1,023,800	87,400	936,400
TOTAL	2,040,100	319,900	1,720,200

Using the Separable Cost-Remaining Benefits method of allocating costs for the purposes of flood control and water supply results in annual costs for flood control of $386,900. With annual benefits of $319,900 for flood control, the benefit-to-cost ratio is .8 to 1 and below the measure of economic justification.

Uxbridge Local Protection

This local protection project would be located along the east bank of the Mumford River in Uxbridge, Massachusetts. It would form an enclosure with dikes and floodwalls to protect the textile manufacturing firm of Emile Bernat and Sons. Recurring losses which are all industrial, at the 1955 flood crest elevation amount to $3,610,700 in June 1979 dollars. Combining stage-damage data with hydrologic stage-frequency relationships provides an estimate of annual losses and benefits to the local protection project. Pertinent annual data with updated annual costs are:

Annual Losses	$114,000
Annual Benefits	102,400
Residual Losses	11,600
Annual Costs	144,700
Benefit-to-Cost Ratio	.7 to 1

The Uxbridge Local Protection Project was not considered for further formulation due to the lack of economic justification. In addition, the Bernat Company has implied that it cannot contribute financially to the project at this time. The firm has developed its own flood reduction program and the town of Uxbridge has joined the Flood Insurance Program (Emergency Program).

Sayles Finishing Company Dam Modification

The Sayles Dam Modification Project area is located in Central Falls, Rhode Island, approximately 80 feet downstream from the Broad Street Bridge. The plan of protection would provide for modifying the existing dam by lowering and replacing the present dam crest with bascule type gates. Recurring losses in June 1979 dollars at a repeat of the 1955 flood crest total $656,900. Damages are heaviest on the left bank where 8 industrial properties, 11 commercial establishments, public housing, a bridge, waterworks, and bank erosion account for $612,200 in losses. On the right bank losses to a bridge, one industrial building, 2 public buildings and river bank erosion total $44,700. The combination of stage-damage data with hydrologic stage frequency data results in the following annual values.

Annual Losses	$ 66,200
Annual Benefits	61,100
Residual Losses	5,100
Annual Costs	$127,500
Benefit-to-Cost Ratio	.5 to 1

The above benefit-to-cost ratio indicates that the Sayles Dam modification is not economically justified at this time.

Old Slater Mill Dam Modification

Located in Pawtucket, Rhode Island, the Old Slater Mill Dam site is historically significant in that the Slater Mill was the first successful cotton spinning operation in the United States. The proposal at the site consists of the lowering and replacing of the present dam crest with bascule type gates. This modification will permit passage of flood flows equal in magnitude to the August 1955 flood of record thus, preventing backwater flooding of commercial and industrial properties. Recurring losses in the Slater Mill area at the 1955 flood crest in June 1979 prices amount to $3,820,300. The bulk of the losses (89%) occur on the right bank to the following properties: four industrial structures, an apartment house, a parking lot, the City Hall, and Slater Mill plus ancillary facilities. Left bank damages of approximately $417,600 stem from four industrial structures, five commercial structures and Pawtucket High School. Combining stage-damage data with hydrologic stage-frequency data results in the following annual values.

Annual Losses	$591,200
Annual Benefits	350,300
Residual Losses	240,900
Annual Costs	470,600
Benefit-to-Cost Ratio	.7 to 1

The less than unity benefit-to-cost ratio indicates that the Old Slater Mill Dam Modification Project is not economically justified at present.

Ashton Local Protection

Located along the easterly bank of the Blackstone River in Cumberland Rhode Island, the project would consist basically of an earth dike and concrete floodwalls. The plan would provide protection against the Standard Project Flood for the 10 acres of land within the U-shaped facility. Recurring losses in the project area are all industrial and stem from damages to the Owens-Corning Fiberglass Company building. A repeat of the 1955 flood crest in the Ashton project area would result in recurring losses of $2,860,000 at the June 1979 price level. The following annual values result from combining stage damage data with hydrologic stage-frequency data.

Annual Losses	$438,000
Annual Benefits	374,600
Residual Losses	63,400
Annual Costs	740,100
Benefit-to-Cost Ratio	.5 to 1

The benefit-to-cost ratio for the Ashton Local Protection Project indicates the lack of economic justification at this time. It should be noted that directly downstream of Ashton project area is the

proposed Berkeley Local Protection Project. This local protection project is located in close proximity to the Owens-Corning property and causes higher than natural flood stages to occur. In the occurrence of a flood of the 1955 magnitude the flood stage at Ownes-Corning would be increased by approximately seven-tenths of a foot, due to the effect of the Berkeley project. Recurring losses would, therefore, rise from $2,860,000 to 5,120,800. Since the Berkeley Local Protection Project has a positive B/C ratio and the Ashton project does not, further analysis in terms of increased annual losses at Ashton is discussed further in this appendix.

Berkeley Local Protection

The Berkeley project area is also located on the east bank of the Blackstone River in Cumberland, Rhode Island. It is directly downtream from the Ashton study area on property adjacent to Owens-Corning. Like the Ashton project, the Berkely protective works would consist basically of an earth dike and concrete floodwalls. Located on the 70 acres protected by the U-shaped facility are four large industrial buildings and some public facility and utilities. Recurring losses at the 1955 flood elevation under present day development conditions amount to approximately $28,006,800 (June ´81 P.L.). Industrial losses account for 97 percent of this total. Annual data (June ´81 P.L.) are as follows:

Annual Losses	$918,700
Annual Benefits	698,100
Residual Losses	124,600
Annual Costs	517,300
Benefit-to-Cost Ratio	1.35 to 1

Since the plan is economically justified, a detailed analysis of benefits and costs is discussed further in this appendix. The nonstructural plans for Berkeley are also discussed in detail.

Railroad Study

The main line of the Providence and Worcester Railroad runs from Providence, Rhode Island to Worcester, Massachusetts along the Blackstone River. Various types of losses, both physical and nonphysical, would be incurred by railroad related facilities in the event of flooding. Measures to reduce or eliminate flood losses and benefits accruing to these measures are discussed below.

A recurrence of a storm of the intensity of Hurricane Diane (August 19, 1955) would result in extensive damage to Providence and Worcester Railroad properties along the Blackstone River. The principal factor occasioning these losses would be streambank erosion caused by the high water flows. Other damage would occur as a consequence of overland flooding. Physical and non-physical losses are to be expected after such an event. The undermining of roadbed

consequent to bank erosion would necessitate trackwork estimated to cost $8,050,000 (June 1979 dollars). Additional physical losses to include bridges, culverts, crossings and equipment would occur in the vulnerable areas. Accompanying non-physical losses would result to car revenues, overtime, car rerouting, and office and computer shutdown time. Total recurring losses are estimated to be $13,959,000.

Railroad Damage

Zones	Towns
4	Millbury
5	Millbury
5	Grafton
7	Blackstone
9	Cumberland, Lincoln

The combination of stage-damage data the hydrologic stage frequency data results in the following annual relationships. Annual losses amount to $140,300. If complete protection were afforded to railway facilities, annual benefits would be equal to the annual loss. However, due to the nature of railroad structures, lesser protection results in substantially lower benefits.

Level of Protection	Annual Benefits
25 Year Event	$ 5,800
50 Year Event	16,100
100 Year Event	38,000

The 1955 storm has a frequency in year of 140 or rarer except in Zone 9 where it is approximately 90.

Officials of the Providence and Worcester Railroad were contacted for estimates of total track miles susceptible to damage from flooding. Between 8 and 15 miles of railroad track would be damaged. Two schemes of protection were designed and costs estimated for both the 8 and 15 mile lengths. Costs per foot for Scheme A amount to $285.00 and $500.00 for Scheme B. At this time, annual costs are far in excess of annual benefits for any plan of protection to be justified.

Scheme/Track Length	Annual Costs	Annual Benefits	Benefit-to-Cost Ratio
Scheme A/8 miles	$ 802,600	$38,000	.05 to 1
Scheme B/8 miles	1,408,000	38,000	.03 to 1
Scheme A/15 miles	1,504,800	38,000	.03 to 1
Scheme B/15 miles	2,640,000	38,000	.01 to 1

Summary of Project Economics

The following summary table displays the benefit-to-cost ratios for the seven previously discussed project areas.

Summary of B/C Ratios for Potential Projects in the Blackstone River Basin

Project	Benefit-to-Cost Ratio
Nipmuc Dam and Reservoir	.8 to 1
Uxbridge Local Protection	.7 to 1
Sayles Dam Modification	.5 to 1
Old Slayter Mill Dam Modification	.7 to 1
Ashton Local Protection	.5 to 1
Berkeley Local Protection	1.35 to 1
Railroad	Range from .01 to 1 to .05 to 1

The Berkeley Local Protection Structural Plan is the only one economically justified and will now be discussed in detail, along with its nonstructural alternative.

EXTENT AND CHARACTER OF THE BERKELEY PROJECT AREA

The Berkeley area is located on the east bank of the Blackstone River in Cumberland, Rhode Island. Located on the 70 acre site are four large structures utilized by two industrial concerns and a commercial distribution firm. In addition, a municipal pumping station and elevated sewer lines are located on the site and the railroad tracks of the Providence and Worcester Railroad extend through the entire lenghth (See Plate 3 for Plan A in main report).

Damage Survey

Previous detailed flood damage surveys were undertaken in the Berkeley Industral Park following the flood of 1955 and again in 1963 and 1975. Due to indications of expansion in both physical size of plant and level of operations, a detailed in-depth damage survey and analysis was undertaken again in September 1979. Elevations of flooding during previous events and elevations of the start of flooding at various locations were ascertained and referenced to the record event (1955 flood). On-site inspections of grounds, structures, machinery, contents and inventory were made. Company professionals such as plant managers, facility engineers, and comptrollers were interviewed to obtain data on previous flooding, current value of plant, contents etc., and the potential finanacial impact of future flooding. Inquiries were also made to determine the nature of the manufacturing and/or distribution process for each company and the resultant impact of curtailment of these activites due to

potential flooding. Data on expansion of physical capital and movements in levels of manpower and payrolls since the last damage survey were also obtain. The end product of the damage survey process was an array of total financial losses (both physical and non-physical) beginning at the elevation at which damages start to the elevation three feet above the flood of record.

Recurring Losses

A recurrence of flooding to the elevation of the 1955 flood (72.49' NGVD) in the Berkeley project area under September 1979 development and activity levels would result in losses of approximately $28,006,700. (See Table 7-4). Dollar damages would be distributed among the specific activities in the following amounts and magnitudes.

TABLE 7-4
Berkeley Project Area
Recurring Losses; Referenced to 1955 Flood Crest
(1981 Price Level)

Activity	Amount	Percent
Industrial	$19,747,300	70.5%
Commercial	$ 7,317,200	26.1%
Public	$ 95,500	0.3%
Railroad	847,200	3.0%
Total	$28,006,700	100.0%

A large and infrequent flood of the magnitude of the Standard Project Flood (approximately the elevation of the 400 year event in the Berkeley area) would result in recurring losses of approximately $49,914,000.

It is significant to note the magnitude of non-physical losses in the Berkeley area. The three companies collectively account for non-physical losses of $6,018,000 at the flood of record. Nine hundred jobs are located in these companies with payrolls totalling $249,000 weekly and $13,000,000 annually. In addition to the direct effects that flooding would have on production, distribution, jobs, wages and profit in Cumberland, Rhode Island, certain indirect effects to other activities in other locations would occur due to the nature of the firms in the Berkeley area. One commercial firm is a distributor of food throughout Rhode Island and neighboring New England states. Twenty-five trailer trucks and a 260,000 square foot warehouse are utilized in the distribution operation. The company is also under contract to the State Civil Defense Agency as the emergency flood distributor during periods of disaster. Another of the companies manufactures clothing and utilizes one of the structures in the project area as a distribution center for raw materials which are transported

to fourteen finishing plants throughout the country. Since the fourteen plants are company owned, significant layoffs and loss of wages and profit would result from the flood-induced supply disruption at Berkeley.

Annual Losses and Benefits - PLAN A

Stage-damage information obtained by field survey is combined with hydrologic stage frequency data to produce damage-frequency correlations. The probability of reaching each specific flood stage during a given year is multiplied by the corresponding damage and the total of expected values resulting in annual losses. Based on the 1979 level of development in the Berkeley area, the average annual innundation loss amounts to $918,700. (See Figure 7-1). The annual benefit based on innundation reduction is calculated by comparison of annual losses without the project to residual annual losses with the project in place. The plan of protection at Berkeley is an earthen dike and floodwalls which afford protection up to the elevation of the Standard Project Flood. The elevation of the SPF approximates that of the 400 year event (.25%) at 76.2 NGVD. Losses without the project, as previously mentioned, are $918,700 and with the project in place are $124,600, resulting in an annual gross benefit of $794,100. It has been determined, however, that the dike at Berkeley would result in slightly higher flood stages at the adjacent Owens-Corning property directly upstream. Hydrologic computations indicate that the increased stage effect caused by the Berkeley LP structure begins at approximately the 40 year event (EL 70.0 NGVD). At the elevation of the 1955 event (EL 77.0 NGVD) the effect is an increase in stage of 0.7 feet. Annual losses, at the SPF, at the Owens-Corning site are increased from $449,000 to $545,000 due to the downstream dike at Berkeley. This "negative benefit" of $96,000 must be subtracted from the innundation reduction benefit at Berkeley to have a true measure of net annual benefit.

Innundation Reduction Benefit	$ 794,100
Negative Benefit	96,000
Net Benefit	698,100

Future Benefits

Through on-site inspections and consultations it was ascertained that the project area is already intensely developed and utilized with vacant industrial land in scarce supply. Flood plain zoning is currently in force thus restricting future development without a plan. Therefore, no benefits are expected to accrue from future development.

COSTS

First Cost - Plan A

The estimate of First Cost are for construction of the project as described in Appendix 4. Quantities were estimated on the basis of a perliminary design. Unit costs are based on February 1981 prices. Engineering Design, Supervision and Administration costs are estimated lump sum items based on similar projects. Details of the February 1981 cost estimates updated by 3 percent to June 1981 using the ENR:CCI Index are presented in Table 7-5.

Annual Costs - Plan A

Estimates of annual costs are based on a 100-year period of analysis and include interest paid during construction. Interest and amortization charges are based on an interest rate of 7-3/8 percent. Table 7-6 summarizes the estimated annual costs.

TABLE 7-5
PLAN A
FIRST COST - BERKELEY LOCAL PROTECTION

Description	COSTS Feb. 1981 P.L.	Increase 3% Jun. 1981 P.L. (Rounded)
Lands & Damages (w/Contingency)	$ 162,960	$ 168,000
Relocations (w/Contingency & EDSA)	$ 56,250	$ 58,000
Levees	$1,786,050	$1,840,000
Floodwalls	972,000	1,001,000
Drainage	171,750	177,000
Sluice Gate & Access Bridge	20,400	21,000
Pumping Station	516,708	532,000
Swing Gates	349,870	360,000
Ponding Area	12,400	13,000
Subtotal, excludes L&D & Rel.	$3,829,178	$3,944,000
Contingencies (20%)	765,836	789,000
SUBTOTAL	$4,595,014	$4,733,000
Engineering & Design (15%)	689,252	710,000
Supervision & Administration (10%)	459,501	473,000
Subtotal, excludes L&D & Rel.	$5,743,767	$5,916,000
TOTAL FIRST COST, Incl. L&D & Rel.	$5,962,977	$6,142,000

TABLE 7-6
BERKELEY LOCAL PROTECTION PLAN A

ANNUAL CHARGES
(June 1981 P.L.)

INVESTMENT

Total Plan A	FIRST COST	$6,142,000
Interest During Construction		
	7-3/8%, 2 years	453,000
	TOTAL INVESTMENT	$6,595,000

ANNUAL CHARGE

Interest & Amortization,	
7-3/8%, 100 years (.07591)	$ 500,600
Maintenance & Operation	14,200
Interim Replacements	2,500
TOTAL ANNUAL CHARGE	$ 517,300

The estimated annual costs, annual benefits, annual net benefits and the ratio of benefits to costs for the Berkeley Local Protection (Plan A) are displayed in Table 7-7.

TABLE 7-7

SUMMARY OF ECONOMIC ANALYSIS - PLAN A
June 1981 Price Level

Average Annual Benefits	$698,100
Average Annual Costs	517,300
Average Annual Net Benefits	$180,800
Benefit-to-Cost Ratio	1.35 to 1

The above analysis indicates that the plan of improvements to provide structural flood protection to the Berkeley Industrial Park is economically justified.

Internal Rate of Return

In accordance with the WRC Manual, a specific check should be included in a flood control report. The internal rate of return is the rate of interest at which benefits equal costs over the period of analysis (i.e., the benefit to cost ratio equal 1.0). The rate of interest used in the computation of benefits and costs was 7-3/8% and the project life or period of analysis numbered 100 years.

Annual Cost = $517,300
Annual Benefit = $698,100

Allowing the annual cost to rise to the level of annual benefits is performed by solving for the appropriate capital recovery factor and ascertaining the corresponding interest rate. The internal rate of return for the Berkeley local protection Plan A is 11-1/2%.

NON-STRUCTURAL BENEFIT ANALYSIS FOR BERKELEY PROJECT AREA

Benefits estimated in the following sections are those which accrue through the implementation of non-structural flood control plans for the major properties within the Berkeley Industrial Park. Estimated in accordance with the WRC Manual, benefits were evaluated for the following two cases of non-structural flood protection: (1) floodproofing each individual property and (2) relocation of each activity outside the flood plain. Benefits accruing to floodproofing were estimated by comparison of average annual flood damages under the with and without project conditions. Benefits accruing to the implemention of a relocation program were examined under the following categories: (1) the net income earned by activities occupying the flood plain with the project and (2) that portion of the flood damage reduced by the project which is borne by occupants outside the flood plain.

Benefits to Floodproofing - Plan B

Floodproofing, including waterproofing and ringwalls in Plan B, were designed and costs estimated for the Okonite Comapny, Roger Williams Foods, the Health-Tex main plant and town pump station. Individual data sheets from the damage survey were examined to determine total physical losses per structure. Non-physical losses do not enter into the analysis as floodproofing does not affect them. Annual benefits are the difference in annual physical losses up to elevation of the 100 year frequency storm with and without floodproofing. Since this technique involves individual structures each one must be economically justified on its own benefits. Cost and benefits are not totalled as in structural flood control analysis; individual economic justification is required. Stage damage and damage frequencey curves were prepared for the four aforementioned properties. Annual physical losses for each property were taken off each damage frequency curve up to the 100 year frequency flood. The annual losses thus become the benefits as this dollar amount of physical loss will be prevented by implementation of Plan B. Table 7-8

summarizes Plan B's costs (Appendix 4) and annual charges, for both a 20 year and 50 year life. Table 7-9 displays: total annual physical losses, benefits accruing to each floodwall plan, annual costs and the benefit-to-cost-ratio.

TABLE 7-8

PLAN B

FIRST COSTS AND ANNUAL CHARGES
June 1981 Price Level

	Health-Tex	Roger Williams	Okonite Co.	Pump Station
FIRST COSTS				
Lands & Damages	$ 22,000	$ 22,200	$ 15,200	-0-
Waterproofing	$ 34,500	$ 21,700	$ 24,000	$ 2,100
Floodwalls	198,900	287,300	3,000	-0-
Flood Gates	60,000	47,500	-0-	-0-
Flood Shields	19,800	4,800	4,500	3,600
Pump Station	20,000	40,000	-0-	-0-
Subtotal, excl. L&D	$ 333,200	$ 401,300	$ 31,500	$ 5,700
Contingency, 20%	66,600	80,200	6,300	1,100
Subtotal	$ 399,800	$ 481,500	$ 37,800	$ 6,800
E&D, 15%	60,000	72,200	5,700	1,000
S&A, 10%	40,000	48,200	3,800	700
Subtotal	$ 499,800	$ 601,900	$ 47,300	$ 8,500
First Cost incl. L&D	$ 521,800	$ 624,100	$ 62,500	$ 8,500
ANNUAL CHARGES				
Interest & Amort. @ 7-3/8% @				
50 yrs. (0.0759)	$ 39,600	$ 47,400	$ 4,700	$ 600
20 yrs. (0.097)	50,600	60,500	6,100	800
Oper. & Maint.	500	600	-0-	-0-
Interim Replace.	100	200	-0-	-0-
TOTAL ANN. CHARGE:				
@ 50 yr. Life	$ 40,200	$ 48,200	$ 4,700	$ 600
@ 20 yr. Life	51,200	61,300	6,100	800

TABLE 7-9

PLAN B

ECONOMIC ANALYSIS
June 1981 Price Level

	Health-Tex	Roger Williams	Okonite Co.	Pump Station
Total Annual Physical Losses	$ 386,900	$ 131,200	$ 70,900	$ 1,300
Average Annual Benefits, Plan B	200,300	77,800	21,500	800
50-YEAR LIFE ANALYSIS:				
Average Annual Costs	$ 39,600	$ 47,400	$ 4,700	$ 600
Average Annual Net Benefit	160,700	30,400	16,800	200
Benefit-to-Cost Ratio	5.1 to 1	1.6 to 1	4.6 to 1	1.3 to 1
20-YEAR LIFE ANALYSIS:				
Average Annual Cost	$ 50,600	$ 60,500	$ 6,100	$ 800
Average Annual Net Benefit	149,700	17,300	15,400	-0-
Benefit-to-Cost Ratio	4.0 to 1	1.3 to 1	3.5 to 1	1.0 to 1

It can be seen from the benefit-to-cost ratios above that implementations of a non-structural plan involving individual floodproofing is economically justified.

Benefits to Relocation

The second alternative non-structural plan for the three flood prone in the Berkeley Industrial Park is relocation out of the flood plain. Benefits for this alternative were assessed under the following categories: (1) the net income earned by activities occupying the flood plain with the project, (2) reduction of external costs based on flood damages to utility transportation and communication systems, (3) reduction of external costs associated with the subsidized portion of Federal flood insurance, (4) reduction of external costs associated with flood emergency activities; and, (5) a positive externality under the "with project" condition. (See Table 7-11).

(1) The most likely future of the area vacated by relocation of the three industrial structures will be green, open space, e.g., a park with few structural amenities. The predominant use of this newly created open space in the flood plain would be passive recreation. To compute a benefit for this new

use involves estimating the additional number of people that the new open space would attract to passive recreation multiplied by the projected number of recreator days. An appropriate recreation day dollar value would be attached to each daily use. It seems doubtful whether a significant benefit would accrue to this new land use, since Cumberland residents currently engage in this activity in other parts of the town and in out of town locations and no excess demand is apparent. In addition, a linear park is in the planning stages along the Blackstone Canal in Lincoln, Rhode Island, directly across the river from the project site. This site is more desirable due to the absence of nearby population distribution, present and future recreational facilities, it appears that new use of the flood plain park would result in a benefit so small as to be insignificant.

The next four benefit categories involves the reduction of flood related costs borne by occupants and activities located outside of the flood plain (project area).

(2) Damages to utility, transporation and communication systems would be reduced under the with project condition and represent a reduction in external costs and, therefore, a benefit. Damages were determined from combined damage frequency curves up to the Standard Proejct Flood. Reduction of these damages resulted in an annual benefit of $3,000 at the 1979 price level.

(3) The reduction of the subsidized portion of flood insurance costs results in a national benefits, i.e., a savings to all U.S. taxpayers since tax funded subsidies support national flood insurance payments. The town of Cumberland is currently under the Emergency Program thereby limiting coverage to the first layer of protection. For the three industrial firms to be relocated the coverage limit for structural and contents losses is $100,000, respectively. The subsidized portion of each firm's premium payment for both structural and contents coverage was calculated. After subtracting deductibles, flood insurance savings under the with project condition totalled $3,200 annually.

(4) Flood emergency costs (emergency evaluation, flood fighting, repairs to public facilities) were difficult to estimate for the project area due to lack of recent experience and data limitations. Best estimates based on the nature and scale of development of the activities in the flood plain indicate that an annual costs of $5,000 is not unreasonable and its elimination would result in a benefit to the relocation plan.

(5) A "positive externality" reflects the amenity of living near park land or open space and is measured as the projected increase in market value of property adjacent to the encumbered flood plain. The benefit was not evaluated under the with project condition for the following reasons. There are no residences adjacent to the newly created open space; the immediate area is zoned industrial. Upstream of the project area is an industrial activity. Railroad tracks and two industries abut the back side of the area and a gravel pit and dumping operation are located on the downstream side. Therefore, the highly industrialized nature of the area surrounding the newly created open space precludes the possibility of a positive externality.

TABLE 7-10

BENEFITS TO RELOCATION OF THREE INDUSTRIAL PROPERTIES

Benefit	Annual Amount
Net Income to New Activity	insignificant
Damage Reduction to Utilities, Trans, and Comm. Systems	$ 3,200
Flood Insurance Savings	$ 3,200
Emergency Cost Savings	$ 5,000
Positive Externality	not applicable
TOTAL	$11,200

The annual costs of relocating the three properties have been estimated by NED to be:

Property	Annual Cost
Health-Tex	$1,372,000
Roger-Williams	$1,084,500
Okonite	$ 688,500
Total	$3,145,000

The very low dollar amount of annual benefits which accrue to the relocation plan in relation to the annual costs indicate the lack of economic justification at this time.

The Benefit/Cost ratio for the relocations of the three buildings are 0.004.

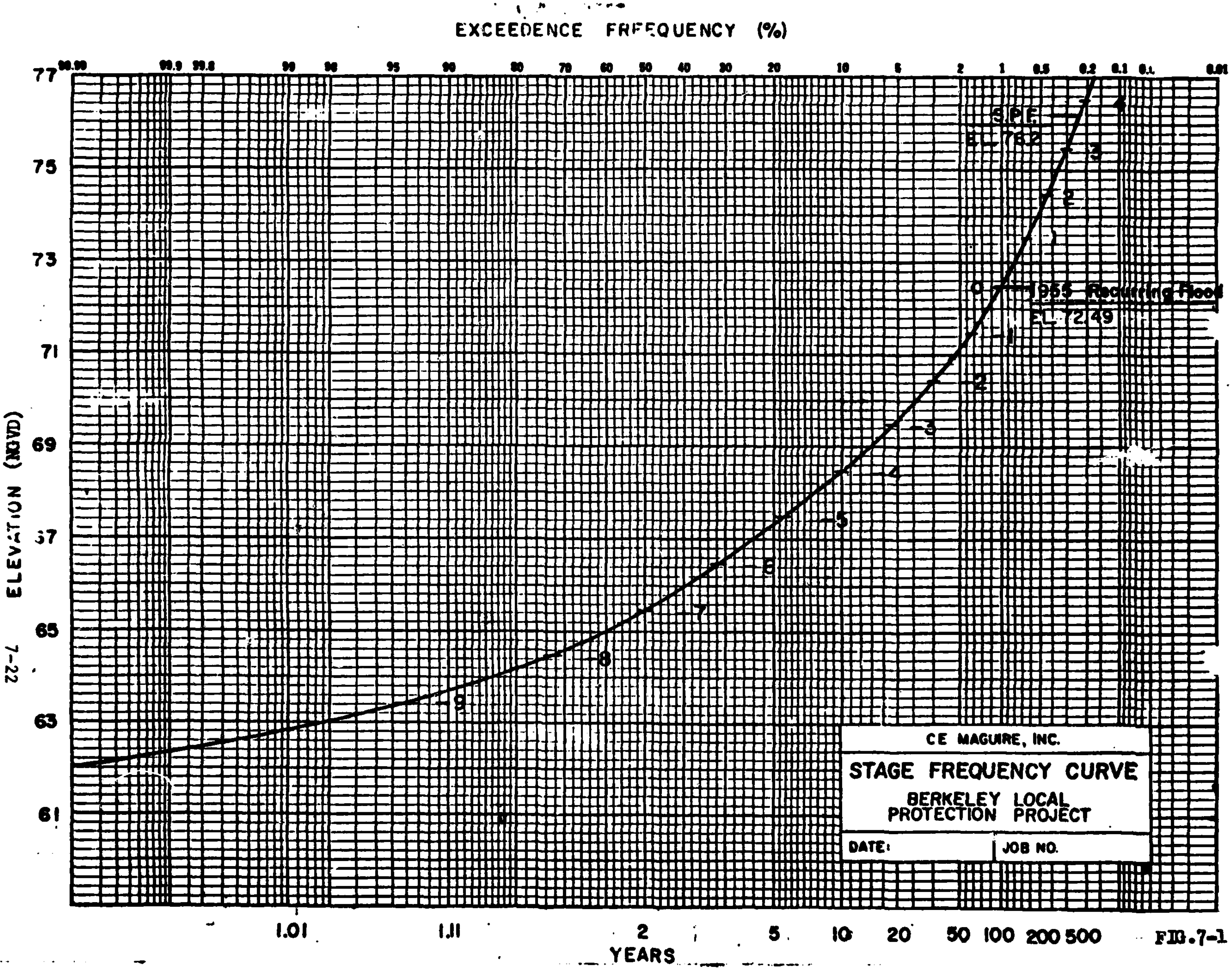
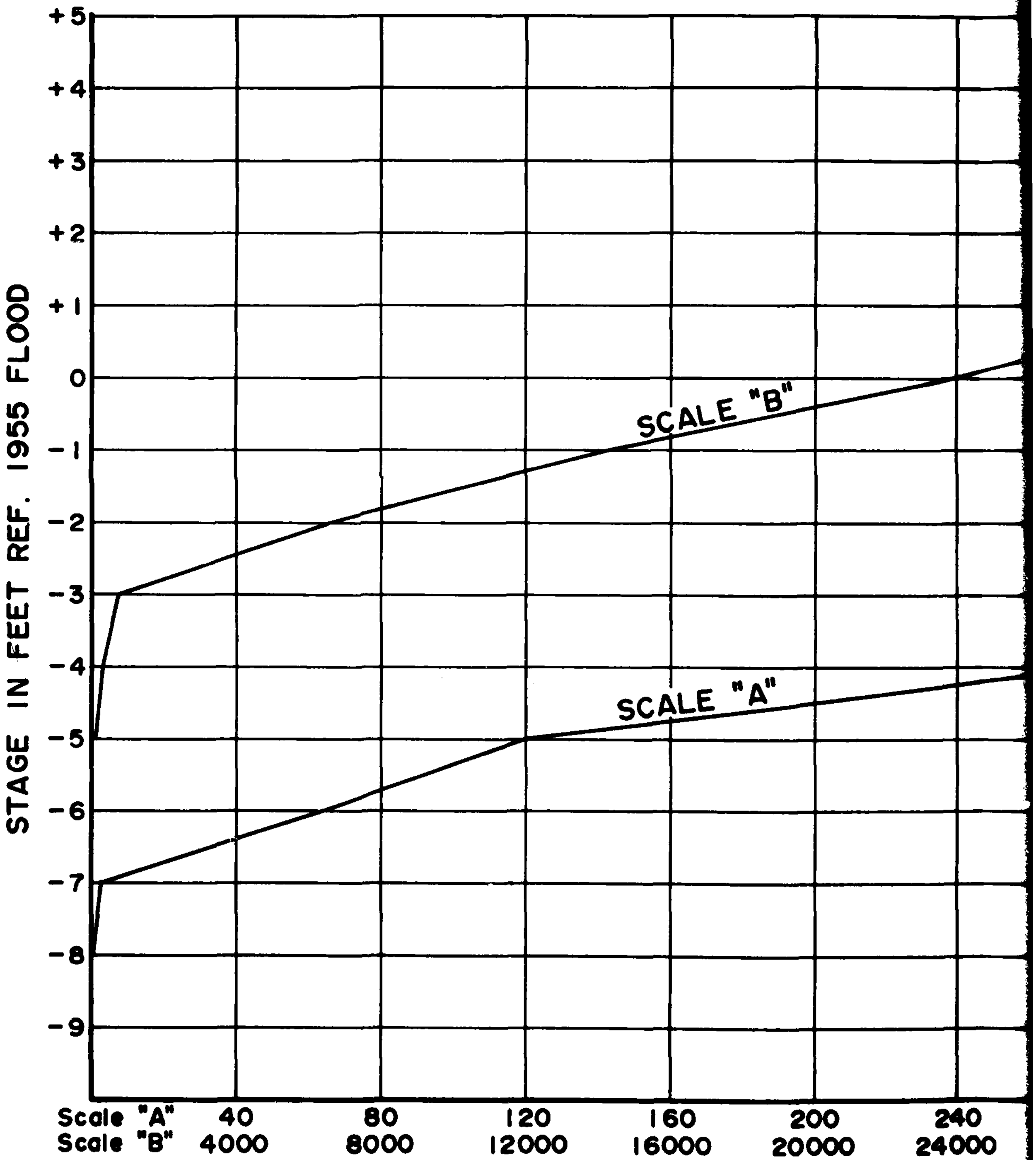
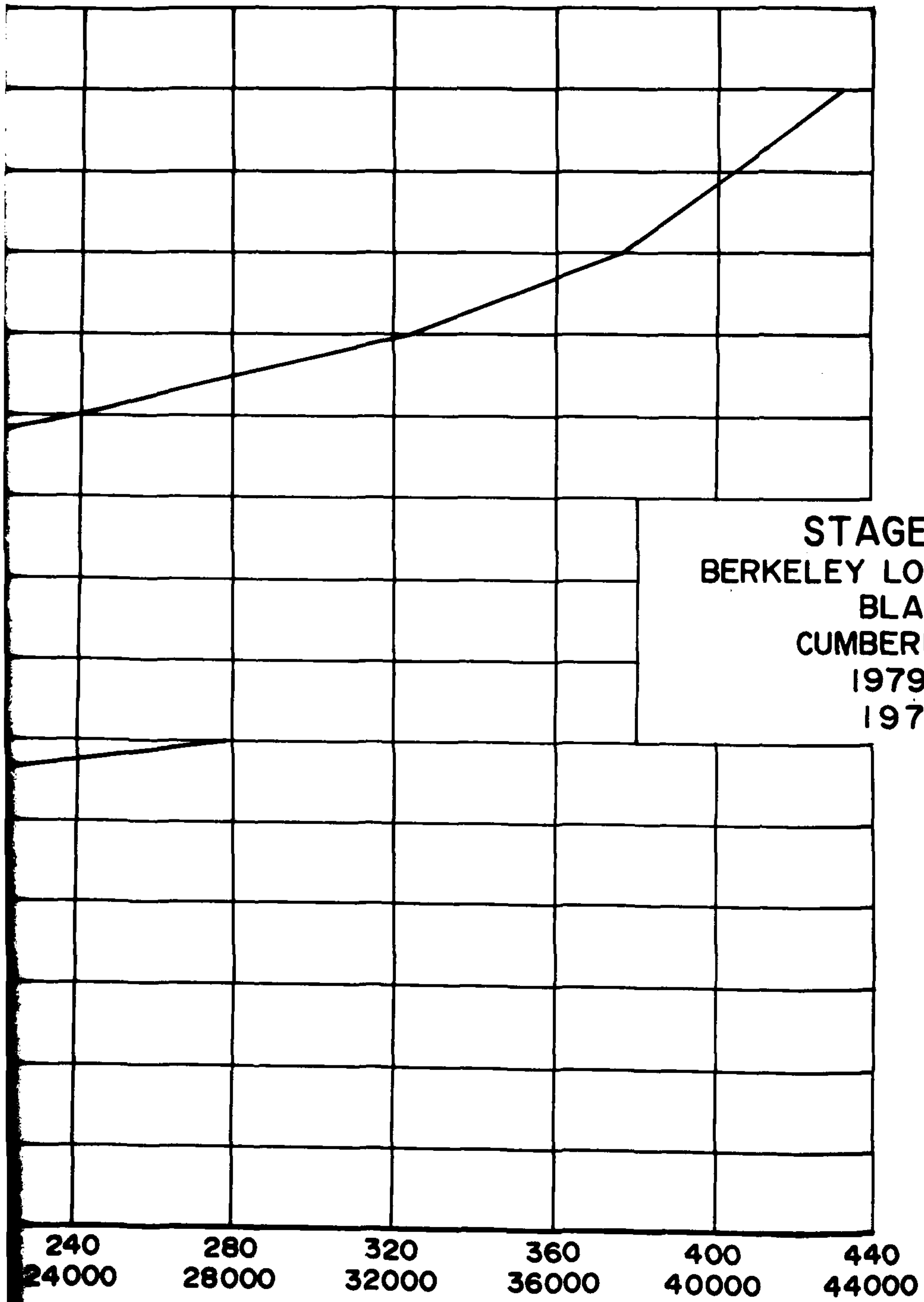

EXCEEDENCE FREQUENCY (%)
ELEVATION (NGVD)
YEARS
S.P.F.
EL 76.2
1955 Recurring Flood
EL 72.49
CE MAGUIRE, INC.
STAGE FREQUENCY CURVE
BERKELEY LOCAL PROTECTION PROJECT
DATE:
JOB NO.

FIG. 7-1

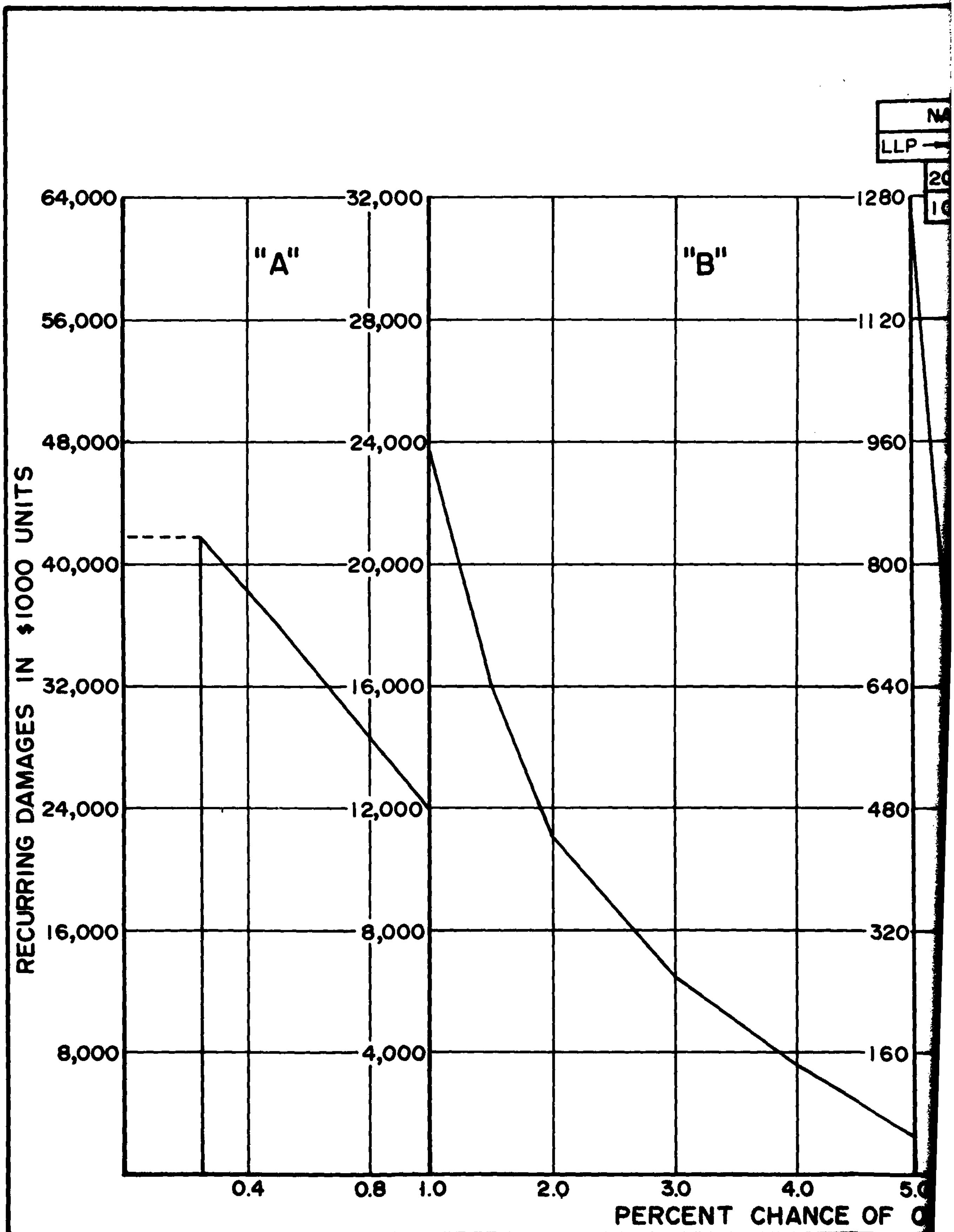

STAGE IN FEET REF. 1955 FLOOD
+5
+4
+3
+2
+1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
SCALE "B"
SCALE "A"
Scale "A" 40 80 120 160 200 240
Scale "B" 4000 8000 12000 16000 20000 24000



STAGE - DAMAGE CURVE
BERKELEY LOCAL PROTECTION PROJECT
BLACKSTONE RIVER
CUMBERLAND, RHODE ISLAND
1979 DAMAGE SURVEY
1979 PRICE LEVEL

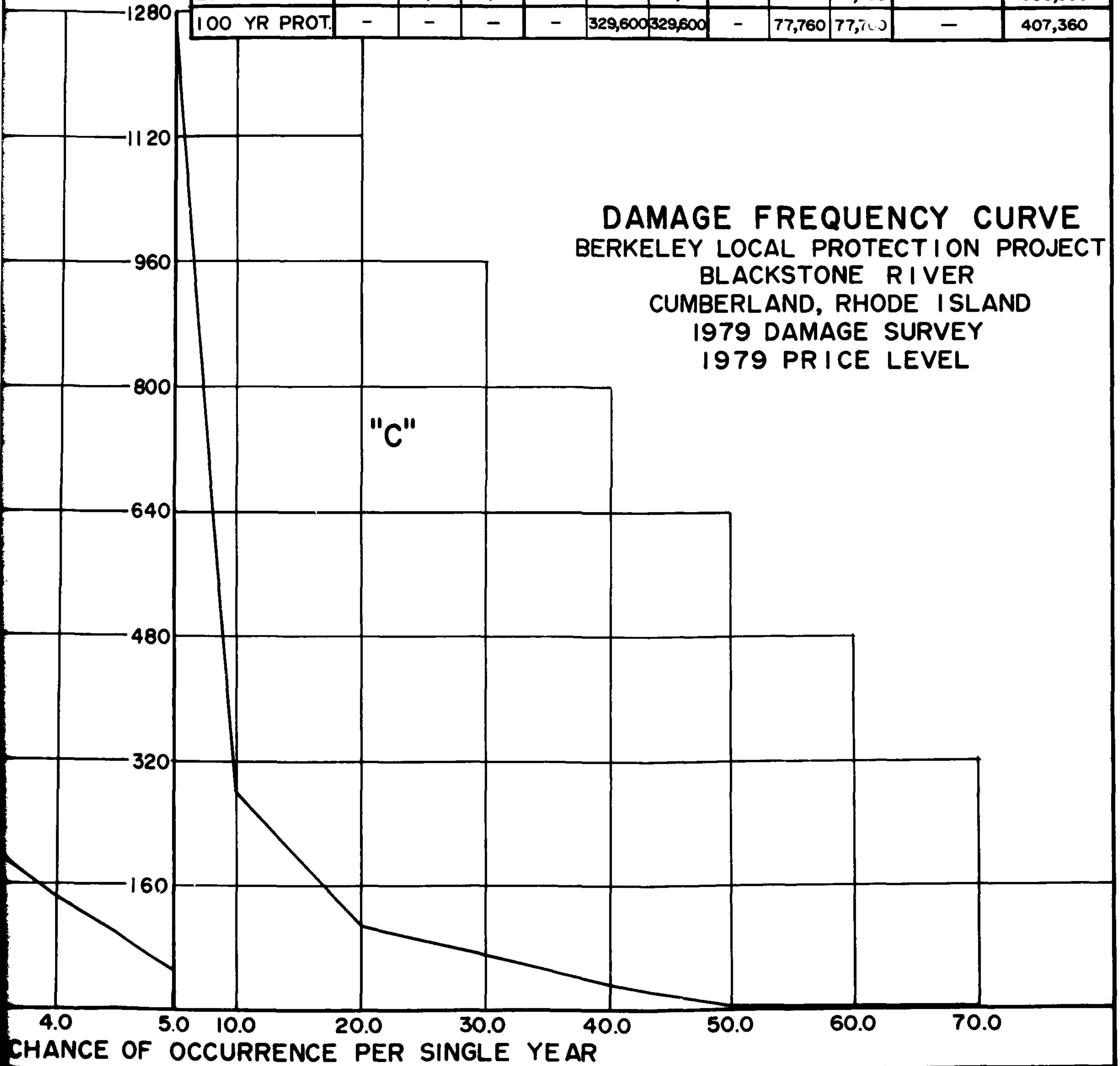
FIGURE 7-2

2



NA
LLP
20
1
"A"
"B"
64,000
56,000
48,000
40,000
32,000
24,000
16,000
8,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
1280
1120
960
800
640
480
320
160
RECURRING DAMAGES IN $1000 UNITS
0.4
0.8
1.0
2.0
3.0
4.0
5.
PERCENT CHANCE OF

	RANGE "A" 1" = $32,000			RANGE "B" 1" = $40,000			RANGE "C" 1" = $16,000			ANNUAL AVERAGE	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN	LOSSES	BENEFIT
NATURAL	11.6	371,200	–	8.24	329,600	–	4.86	77,760	–	778,560	–
LLP → SPF (0.25%)	3.3	105,600	265,600	"	"	329,600	"	"	77,760	105,600	672,960
200 YR PROT.	6.93	221,760	149,440	–	–	329,600	–	–	77,760	—	556,800
100 YR PROT.	–	–	–	–	329,600	329,600	–	77,760	77,7[illegible]	—	407,360



DAMAGE FREQUENCY CURVE
BERKELEY LOCAL PROTECTION PROJECT
BLACKSTONE RIVER
CUMBERLAND, RHODE ISLAND
1979 DAMAGE SURVEY
1979 PRICE LEVEL

FIGURE 7-3

1

2

WATER RESOURCES STUDY

BLACKSTONE RIVER BASIN

MASSACHUSETTS AND RHODE ISLAND

APPENDIX 8

HYDROLOGIC ANALYSIS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

1981

PREFACE

The Hydrologic Analysis reported herein was performed by C. E. Maguire, Inc. of Providence, Rhode Island under contract to the New England Division, Corps of Engineers. A review and some modifications have been made in the report by the Hydrologic Engineering Section of the Engineering Division at NED subsequent to, and as a result of, a stage 3 checkpoint conference held at Waltham on 30 May 1980.

HYDROLOGIC ANALYSIS

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BLACKSTONE RIVER BASIN
HYDROLOGIC ANALYSIS

1. INTRODUCTION

This appendix presents the hydrologic analysis performed for the Water Resources Study of the Blackstone River basin. The report presents hydrologic data and includes analyses of floods of record, flood frequencies, development of the Standard Project Flood and analyses of various flood control measures.

2. HYDROLOGIC DESCRIPTION OF BASIN

a. General. The Blackstone River basin, located in south-central Massachusetts and northern Rhode Island, is generally elongated in shape with a length of about 44 miles, average width of 12 miles, and a total drainage area of 476 square miles. The topography is generally hilly with higher elevations lying in the western portion some of which are in excess of 1,300 feet msl. Because of short, steep tributaries in the upper reaches of the watershed and relatively longer ones in the lower reaches, there is a tendency for the tributary flows to synchronize with the crest on the main river. A map of the Blackstone River basin is shown on plate 1.

b. Principal Stream. The Blackstone River originates at the junction of the Middle River and Mill Brook in the southern part of Worcester, Massachusetts and flows in a generally south-easterly direction for 44 miles to its mouth at the Main Street dam in Pawtucket, Rhode Island. At Main Street dam, Blackstone flows enter the Seekonk River, a tidal estuary continuing 7 miles south to the Providence River in Providence, Rhode Island.

The Blackstone River has a total fall of about 440 feet from its source to sea level. From Worcester to Fisherville, a distance of approximately 10 miles, the river falls 150 feet or about 15 feet per mile. In the next 18 miles to Blackstone, Massachusetts, the average fall is only about 5 feet per mile. The river valley in this second reach is broad and flat and has some modifying effect on floods in the basin. Downstream of Blackstone, the river drops 75 feet in 3 miles, then flattens out to become a rather uniform slope of approximately 11 feet per mile to tidewater. A profile of the Blackstone River is shown on plates 2 through 9.

During the 19th century, several small dams were constructed across the river to develop water power for industrial plants located along its banks. In recent years, a number of these industrial plants

have been abandoned. Most of those remaining buy their electric power and use the dams solely for industrial purposes. Several dams on the Blackstone River and its tributaries were damaged during the August 1955 flood, and some failed at, or near, time of peak flow.

c. Tributaries. Principal tributaries of the Blackstone River are Kettle, Beaver, and Mill Brooks and the Middle River which combine to form the headwaters of the Blackstone River in Worcester, followed, in downstream order, by the tributaries: Quinsigamond, West, Mumford, Branch, Mill and Peter Rivers, and Abbot Run Brook.

(1) Headwater Tributaries

(a) Kettle Brook, located entirely in Massachusetts, originates in the uppermost northwesterly part of the watershed at Reservoir 4 near Paxton Center and drains 32.8 square miles. The brook flows southeasterly through the town of Leicester into Auburn where at Stoneville it turns northerly toward Worcester. Terminus of Kettle Brook is at the outlet of Curtis Pond at the confluence of Beaver Brook, with this point marking the beginning of Middle River. In its entire length of 12.7 miles, Kettle Brook has been extensively developed with reservoirs providing water supply to the city of Worcester and downstream industrial purposes. The Worcester Diversion Project, completed by the Corps of Engineers in 1960, diverts floodflows from 30.5 square miles of Kettle Brook around Worcester.

(b) Beaver Brook with a drainage area of 15.6 square miles rises along the northern city boundary of Worcester approximately 1-1/4 miles westerly of Indian Lake. It flows southward to join Kettle Brook, forming the Middle River at the outlet of Curtis Pond. Approximately 4.2 miles upstream from its terminus, Beaver Brook intercepts its major tributary, Tatnuck Brook on the westerly side. Tatnuck Brook, having a drainage area of 11.3 square miles, originates in the Holden Reservoir in Paxton which is part of the Worcester water supply system.

(c) Mill Brook, located on the easterly side of Beaver Brook watershed and draining approximately 15 square miles, originates near Chaffinville, in the town of Holden. It flows southward through Indian Lake and thence through the center of Worcester to join the Middle River on the southern side of the city. Throughout most of its length, particularly in its most densely populated section below Indian Lake, Mill Brook is enclosed in an underground conduit. There are very few ponds or wetland areas other than Indian Lake, Marshall and Salisbury Ponds.

(d) The Middle River flows generally southeasterly for a distance of approximately 2.5 miles through a wetland area, two ponds and then intercepts Mill Brook to form the Blackstone River at the American Steel and Wire Company dam northeast of Quinsigamond Village in Worcester. At this point, it has a total drainage area of about 65 square miles of which 1.7 are local and lies entirely within the limits of Worcester and Auburn.

(2) Quinsigamond River. This basin lies in Boylston, West Boylston, Shrewsbury, Grafton, Millbury and Worcester, Massachusetts. It has a 12.2 mile length oriented along a north-south axis, a maximum width of 4.5 miles and drains an area of 37 square miles. The river measures about 13 miles in length, of which 8 miles are a succession of lakes, the largest being Lake Quinsigamond with a water surface of 539 acres. This lake is one of three closely related bodies of water (combined area = 929 acres), the other two are Flints Pond with an area of 322 acres, and Hovey Pond with a 68 acre area.

(3) West River. The river, located entirely in Massachusetts, rises in Upton State Forest in the southwest corner of Westboro, three miles northeast of the center of Grafton. It flows in a southerly direction through the towns of Upton and Northbridge joining the Blackstone River about 0.6 mile downstream from the confluence of the Mumford and Blackstone Rivers. In a clockwise direction from its source in the headwaters, Hopkinton, Mendon and Millville are other perimeter towns within the watershed.

The watershed, elongated in shape with a maximum length of about 12.5 miles and a width varying from about 5 miles in the upper portion to approximately 2 miles in the lower section, has a total drainage area of 35 square miles, with 80 percent (27.9 square miles) controlled by the existing Corps of Engineers West Hill flood control reservoir. This reservoir, completed in 1960, is located approximately 3.2 miles upstream from the mouth of the West River.

(4) Mumford River. The Mumford River originates from a system of lakes, ponds and reservoirs in the towns of Oxford, Douglas and Sutton, Massachusetts. It follows a rather sinuous course in a generally easterly direction through Sutton, Northbridge and Uxbridge, where it joins the Blackstone River 0.5 mile east of the business center of Uxbridge.

The basin has a length of 10.9 miles, a maximum width of 8.1 miles and drains an area of 58 square miles. Scattered throughout the watershed are small and large impoundments which are principally utilized for storing process water for finishing textile goods.

(5) Branch River. In terms of drainage area, the largest tributary of the Blackstone River is the Branch River (drainage area 96 square miles), of which 12.6 miles are in Massachusetts and the remainder in Rhode Island. The basin is shaped like an equilateral triangle, with each side approximately 15 miles in length.

The main stem of the Branch River is formed by the confluence of the Chepachet and Pascoag Rivers near the village of Oakland in Burrillville, Rhode Island, and terminates at the Blackstone River in North Smithfield, Rhode Island near the Massachusetts-Rhode Island State boundary. The northern fork of the Branch River (drainage area 44.7 square miles) originates on the Clear River at Wallum Lake in the extreme northwestern corner of Rhode Island and flows in a southeasterly direction through the Wilson Reservoir to join with the Pascoag River just north of the village of Pascoag. The Pascoag River, joined by the Nipmuc River just north of the village of Harrisville, Rhode Island, continues flowing southeasterly to Oakland to form the Branch River. The southern fork (drainage area 21.2 square miles) originates in the swamps upstream of the Smith and Sayles Reservoirs in Glocester, and flows in a northeasterly direction through the village of Chepachet to Oakland, Rhode Island. Another southern tributary Tarklin Brook joins the Branch River at the southwestern extremity of the Slatersville Reservoir near the village of Nasonville, Rhode Island.

The Branch River and its tributaries drain a watershed with a mean elevation of 475 msl, extending from a high elevation of 804 msl at Durfee Hill in northwestern Rhode Island to a low elevation of 180 msl at its junction with the Blackstone River. The main stream slope averages 16.0 feet/mile. Scattered throughout the hilly terrain of the basin are many lakes, ponds and artificial reservoirs which were originally developed for processing of industrial goods in connection with textile manufacturing and finishing. Table 1 lists pertinent data relating to the existing major impoundments of the Branch River basin (for surface areas greater than 100 acres). Branch River profiles are shown on plates 10 through 14.

(6) Mill River. The Mill River has its source at North Pond in the towns of Hopkinton, Upton and Milford, Massachusetts and flows southerly for 15 miles through Mendon and Blackstone, Massachusetts to the Blackstone River, a short distance above the U.S. Geological Survey gaging station at Woonsocket, Rhode Island.

The basin (drainage area 35 square miles) is located almost entirely within the Commonwealth of Massachusetts and is elongated in

TABLE 1

PERTINENT DATA FOR RESERVOIRS IN BRANCH RIVER BASIN

Reservoir	Location	Purpose	Drainage Area (sq. mi.)	Stream	Gross Capacity Surface Area (acres)	Estimated** Storage (ac-ft)	Equivalent Runoff (inches)	Overflow Elevation (msl)
Wallum Lake	Burrillville, Rhode Island	Flood Control Water Supply	2.35	Clear River	322	1,600	12.7*	586
Wilson Reservoir	Burrillville, Rhode Island	Recreation	11.47	Clear River	114	800	1.3	439
Keech Pond	Glocester, Rhode Island	Recreation	1.87	Chepachet River	53	100	1.0	426
Burlingame	Glocester, Rhode Island	-	1.95	Pascoag River	67	135	1.3	594
Pascoag Reservoir	Burrillville-Glocester, Rhode Island	Recreation	8.47	Pascoag River	352	3,520	7.8*	441
Smith & Sayles Reservoir	Glocester, Rhode Island	-	7.86	Chepachet River	175	350	.83	424
(Upper & Lower) Slatersville Reservoir	No. Smithfield-Burrillville, Rhode Island	Recreation	89.60	Branch River	227	1,800	.38	249-230
Tarklin Reservoir Pond	North Smithfield Rhode Island	-	8.66	Branch River	20	100	.22	279
					1,330	8,405		

*Runoff in inches and storage capacity is excessive compared to its drainage area, and these reservoirs are not likely to be filled up.
**From U.S.C. and G.S. Maps

shape, being 10 miles long with an average width slightly in excess of 2 miles.

The largest impoundment within the basin is Harris Pond located almost entirely within Blackstone, Massachusetts, with the dam and appurtenant structures straddling the Woonsocket city limits on the Rhode Island-Massachusetts State Line. During the record flood of August 1955, this dam failed and compounded the flood problems within one section in the northern quadrant of Woonsocket. Since then it has been rebuilt by the city as one of its main sources of water supply.

Subsequent to the disastrous flood of 1955, the Lower Woonsocket Local Protection Project was completed by the Corps of Engineers in 1967. This project consisted of channel improvements, dikes, walls, drains, pressure conduits, pumping stations and dam removals. The Mill and Peters Rivers enter the Blackstone in adjacent pressure conduits.

(7) Peters River. The Peters River has its origin north of Silver Lake in Bellingham, Massachusetts. From Silver Lake, the Peters River flows southerly for approximately 3.5 miles before crossing the Massachusetts-Rhode Island State Line at Woonsocket. Approximately 1 mile further downstream, the Peters joins the Blackstone River in a pressure conduit at the Lower Woonsocket local project. The river basin averages about 2 miles in width, 5 miles in length and has a drainage area of 12 square miles.

(8) Abbot Run Brook. This brook originates, respectively, in the towns of Wrentham and Cumberland along the Massachusetts and Rhode Island State Line. A short distance from its origin, it is impounded in the Diamond Hill Reservoir which supplies water to Pawtucket. From the reservoir, Abbott Run flows south for approximately 2 miles through some small ponds, crossing the State Line into North Attleboro, Massachusetts. It then meanders in a southerly direction for another three miles, again crossing the State Line. Abbott Run joins the Blackstone River in the village of Valley Falls in Cumberland, Rhode Island.

The watershed is about 11 miles long and roughly 3 miles wide with a total drainage area of 27 square miles. It is characterized by many swamps and several small ponds with hilly topography more pronounced along the outer fringes.

3. CLIMATOLOGY

a. General. The Blackstone River basin has a variable climate characterized by frequent but generally short periods of heavy

precipitation which is distributed quite uniformly throughout the year with much of it occurring as snow during the winter months. The drainage basin lies in the path of the "prevailing westerlies" and other cyclonic storms that move easterly across the country from the western or southwestern United States. Because of its proximity to the sea, it is also subjected to coastal storms, locally known as "northeasters", which travel up the Atlantic Seaboard from the Carolinas, occurring mostly durng the fall and winter months. Intense rainfall in combination with a melting snow cover can result in flood producing runoff. In addition, tropical hurricanes constitute an infrequent but very important potential for flood-producing precipitation, particularly from July to October. Thunderstorms may occur over the basin at any time of the year and may be of local origin or associated with a stationary front.

b. Temperature. Average annual temperature of the Blackstone River basin is about 49° Fahrenheit. Average monthly temperatures vary widely throughout the year, from 25° in January to 73° in July. Extremes in temperature may range from occasional highs above 100° to infrequent lows below 10° Fahrenheit. Long term temperature records, available for Worcester and Providence, are summarized in table 2.

c. Precipitation. The mean annual precipitation over the basin is about 42 inches distributed rather uniformly throughout the year. Average monthly rainfall at Providence ranges from a minimum of 2.98 inches in June to a maximum of 3.84 in December and at Worcester, from 3.19 inches in February to 4.01 in August. Average monthly precipitation values are listed in table 3.

d. Snowfall and Snow Cover. About one-third of the precipitation that occurs during the winter months is in the form of snow. Annual snowfall for the entire basin varies from 55 to 60 inches, with extremes ranging from 40 inches in the southern portions to about 60 inches at inland points to the north. In recent years, surveys of snow cover have been taken regularly in the Blackstone basin. The mean annual water content of the snow cover over the basin seldom exceeds 3 inches. On occasions, however, a maximum water content of more than 6 inches has been experienced in the upper Blackstone basin. Moderately high springtime discharges frequently occur as the result of melting snow, but runoff from this source alone generally has been insufficient, during the period of record, to cause a major flood. However, serious flooding due to a combination of heavy rain and snowmelt is a possibility nearly every year. Tables 4 and 5 summarize data on snowfall and snow cover.

TABLE 2

MEAN MONTHLY TEMPERATURES

Month	Worcester, Mass. 69 Years of Record Mean	Maximum	Minimum	Providence, R.I. 45 Years of Record Mean	Maximum	Minimum
January	25.3	69	-18	29.3	68	-13
February	25.8	67	-24	29.4	69	-17
March	34.8	84	- 6	37.6	90	1
April	45.3	91	8	47.6	98	11
May	57.2	93	25	53.5	95	32
June	65.9	96	33	67.0	101	39
July	70.8	102	41	72.7	101	49
August	68.9	99	38	71.0	104	40
September	61.9	100	26	63.8	99	33
October	51.6	89	18	53.9	90	20
November	40.0	81	3	43.2	82	9
December	28.4	67	-17	32.6	69	-12
Annual	48.0	102	-24	50.1	104	-17

TABLE 3

MEAN MONTHLY PRECIPITATION

	Worcester, Mass. 112 Years of Record Elev. 628 Feet msl			Providence, R.I. 74 Years of Record Elev. 51 Feet msl		
Month	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	3.63	11.16	0.70	3.63	7.12	0.50
February	3.20	8.09	0.67	3.29	5.80	1.18
March	3.85	11.13	0.04	3.70	8.31	0.07
April	3.60	10.77	0.35	3.54	7.32	0.72
May	3.74	8.84	0.76	3.13	9.25	0.57
June	3.36	9.25	0.66	2.97	7.21	0.04
July	3.62	11.41	0.62	2.43	8.08	0.24
August	3.96	18.58	0.35	3.61	12.24	0.78
September	3.67	13.13	0.20	3.35	9.79	0.48
October	3.65	11.67	0.36	3.09	11.89	0.15
November	3.84	10.40	0.56	3.69	8.50	0.31
December	3.64	9.83	0.78	3.86	10.75	1.05
Annual	43.92	71.66	27.92	40.29	65.06	25.44

TABLE 4

MEAN MONTHLY SNOWFALL (DEPTH IN INCHES)

	Worcester, Mass. 66 Years of Record Elev. 628 Feet msl	Providence, R.I. 73 Years of Record Elev. 51 Feet msl
January	14.9	9.60
February	15.8	10.2
March	10.2	6.7
April	3.2	0.9
May	TRACE	0.1
June	0.0	0.0
July	TRACE	0.0
August	TRACE	0.0
September	TRACE	0.0
October	0.1	TRACE
November	3.0	1.0
December	10.1	6.6
Annual	57.3	35.1

TABLE 5

WATER EQUIVALENTS OF SNOW COVER (IN INCHES)
BLACKSTONE RIVER BASIN
1957 - 1971

Date	Minimum	Mean	Maximum
1 February	0.0	1.85	3.9
15 February	0.2	2.55	5.2
1 March	0.2	2.75	6.0
15 March	0.0	2.25	5.0
1 April	0.0	0.70	3.3
15 April	0.0	0.00	0.7

e. Storms. Three general types of storms occur in the Blackstone River basin - continental, coastal, and those associated with thunderstorms which may be of local origin or the result of a stationary front. Continental storms originate over the United States and southwestern Canada and move in a general easterly and northeasterly direction. These storms may be rapidly moving intense cyclones, or the stationary type. They are not limited to any season or month but follow one another at more or less regular intervals with varying intensities throughout the year. Coastal storms can be either tropical or extratropical. Tropical hurricanes originate either near the Cape Verde Islands or in the Western Caribbean Sea and generally move in a westerly or northwesterly direction, curving inward to the north as they approach the mainland, and then to the northeast when approaching New England. Although the normal path is to the south and east of New England, they can be deflected over this area by continental cyclonic disturbances or by a large, slow-moving, anticyclonic center, if these are present to the northeast of New England at the time. The latter diversion is known as a "blocking" high pressure cell. For the most part, hurricanes are likely to occur during the months of July through October with greater incidence of such storms during August and September. Coastal storms of an extratropical nature differ from the storms accompanying hurricanes principally if they originate off the Carolina coastline. These storms travel a path that is parallel to the coastline, but more westward than the path of hurricanes, covering a much greater area with precipitation, and occurring most frequently during the autumn, winter and spring months. Thunderstorms may be either of local origin or of the frontal type associated with the summer months.

The greatest storm rainfall for wide area coverage now recorded in New England occurred during 17-19 August 1955, accompanying hurricnae "Diane". This storm exceeded all previous New England records for total rainfall in a single storm and for a 24-hour period. Of particular significance is the fact that less than a week before "Diane", her predecessor "Connie" had deposited a rainfall of 4 to 6 inches or more along the Atlantic coast from North Carolina to southern New England. Consequently, the watersheds were well soaked and streams, reservoirs, and ponds were relatively full when the intense rainfall of 17-19 August 1955 occurred. The amount of precipitation was greater in the upper Blackstone River basin than in the lower basin. At Kettle Brook, near Worcester, a rainfall of 13 to 15 inches was recorded, while at the lower end of the basin, in Pawtucket, the recorded rainfall was 8 inches.

f. Droughts.

(1) General. The long term annual rainfall of approximately 42 inches in the southeastern New England area is really the average

of the annual rainfall for all years of record. When rainfall is below average for a period of time, the area experiences what is referred to as a "drought". In this case, a drought is defined as a prolonged period of precipitation deficiency which seriously affects both riverflow and ground water supplies and represents periods of minimum rainfall.

(2) Drought of 1963-1966. The drought of 1963-1966 in southeastern New England, for its duration, was the greatest ever experienced in the area in 200 years of record. Severity of this drought followed a period of above normal rainfall which contributed to relaxation on the part of cities and towns during a period of rapidly increasing water demand. The drought was more severe in the interior than along the coast. The accumulated deficiency in the average runoff of the Blackstone River at Woonsocket for water years 1964 through 1967 was 27 inches, which is equivalent to more than one year's average runoff.

4. STREAMFLOW

a. Discharge Records. The US Geological Survey publishes records of nine stream gaging stations in the Blackstone River basin, seven of which are on tributaries and two on the main stream. Gaging stations on the tributary streams within the basin are located on Kettle Brook at Worcester (discontinued in 1979), Quinsigamond River at North Grafton, West River below West Hill Dam near Uxbridge, all in Massachusetts, the Nipmuc River near Harrisville, Chepachet River at Chepachet (discontinued in 1975), and the Branch River at Forestdale and a Blackstone River tributary at Woonsocket, all in Rhode Island. On the main stream itself, there are two gaging stations - one at Northbridge, Massachusetts, measuring runoff from about 30 percent of the basin, and the other at Woonsocket, Rhode Island, measuring runoff from about 85 percent of the basin. A gaging station on the Mumford River in East Douglas, Massachusetts, was discontinued in 1951. Pertinent runoff data from the existing gaging stations is compiled in table 6. Locations of the gaging stations are shown on plate 1.

b. Runoff. The mean annual runoff from the Blackstone River for the period of record, adjusted for upstream storage and diversion, is 244 cfs at Northbridge, Massachusetts, 726 cfs at Woonsocket and 165 cfs for the Branch River at Forestdale, Rhode Island. At Worcester, the average runoff from Kettle Brook is 53 cfs for 53 years of record. The instantaneous maximum and minimum flow rates and mean monthly runoff values for these four stations as well as the Nipmuc and Chepachet Rivers are given in table 7. Average annual runoff in the basin is about 1.75 cfs per square mile which is equivalent to about 24 inches of runoff per year or about 57 percent of average annual precipitation.

TABLE 6

STREAMFLOW DATA

Station	Location of Gaging Station	Drainage Area (sq. mi.)	Period of Record	Discharge Average (cfs)	Discharge Minimum (cfs)	Discharge Maximum (cfs)	Date	Datum of Gage (ft. msl)
	Blackstone River Basin							
1095	Kettle Brook; Worcester, Massachusetts	31.3	1923-1979	53.2	0.2	3,970	8/19/55	472.86
1100	Quinsigamond River; North Grafton, Mass.	25.5	1939-P	41.3	0	820	8/20/55	335.00
1105	Blackstone River at Northbridge, Mass.	139.0	1939-P	244.0	2.0*	16,900	8/20/55	260.00
1112	West River below West Hill Dam near Uxbridge, Massachusetts	27.9	1962-P	43.1	1.1*	370	3/26/68	240.00
1113	Nipmuc River near Harrisville, Rhode Island	16.0	1964-P	27.1	0.09	1,020	3/18/68	340.00
1114	Chepachet River at Chepachet, R.I.	17.4	1964-1975	31.4	1.9	1,080	3/18/68	355.00
	Chepachet River at Gazzaville, R.I.	19.2	3/73-P	-	8.1	264	7/1/73	335.00
1115	Branch River at Forestdale, R.I.	91.2	1940-P	165.0	5.2*	5,800	3/19/36	180.00
1125	Blackstone River at Woonsocket, R.I.	416.0	1929-P	725.0	21.0*	32,900**	8/19/55	107.42
1127	Blackstone River Tributary at Woonsocket, Rhode Island	2.31	1965-P	3.45	-	285	3/18/68	150.00

*Minimum Daily Flow
**Includes Failure of Horseshoe Dam

TABLE 7

MEAN MONTHLY RUNOFF (CFS)

Month	*Kettle Brook at Worcester, Mass. (DA=31.3 sq. mi.)			Blackstone River at Northbridge, Mass. (DA=139 sq. mi.)			Blackstone River at Woonsocket, R.I. (DA=416 sq. mi.)			Branch River at Forestdale, R.I. (DA=91.2 sq. mi.)			Chepachet River at Chepachet, R.I. (DA=17.4 sq. mi.)			Nipmuc River near Harrisville, R.I. (DA=16.0 sq. mi.)		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
January	56	123	13	252	546	66	862	1,609	177	198	426	46	34.84	168	8.9	26.43	217	7.0
February	60	127	27	303	828	128	938	2,489	354	226	418	78	50.19	416	8.7	41.08	395	6.6
March	104	313	39	500	1,070	229	1,521	4,056	732	325	547	169	76.30	791	19.0	65.44	764	12.0
April	100	208	29	471	918	166	1,395	2,640	451	287	588	89	55.79	395	7.5	54.25	411	13.0
May	61	121	19	290	594	105	848	1,783	285	192	399	77	40.28	327	6.1	39.20	408	6.3
June	44	133	13	206	629	67	563	1,838	142	106	299	38	27.19	133	3.7	23.88	211	1.5
July	30	163	14	121	417	22	319	2,450	90	52	156	18	12.39	222	3.2	7.82	105	.53
August	30	257	10	118	1,182	16	269	2,688	65	54	372	18	9.0	42	2.0	3.31	28	.36
September	32	169	9	112	796	21	323	1,972	75	68	397	21	8.48	66	1.9	3.62	40	.28
October	30	170	7	120	708	28	340	1,999	100	78	479	16	18.24	128	2.7	5.32	105	.53
November	44	147	11	201	766	41	586	2,233	123	138	472	30	28.65	170	3.8	20.52	284	.63
December	50	139	10	232	603	61	794	2,262	159	179	422	38	41.85	219	4.4	35.15	344	2.8
Annual	53			244			730			165			33.60			27.17		

*Adjusted monthly discharge for 1923-58 may be subject to error because of regulation upstream.

5. HISTORY OF FLOODS

a. General. Major floods on the Blackstone River occur during any season of the year. Rain combined with melting snow resulted in the March floods of 1936, 1968, 1969 and January 1979. Heavy rains of tropical origin during summer and fall months caused the floods of November 1927, July 1938, September 1954, and August 1955.

b. Historic Floods. The flood history of the basin extends back more than 160 years. Records concerning early floods, although meager in most cases, mention March 1818, March 1823, February 1866, March 1876, February 1886 and September 1887. The greatest occurred in February 1886 and exceeded any previous event for which information is available. The storm, lasting about 60 hours, had a maximum rainfall of 5.65 inches near Providence, and about 2 inches of water was added to the runoff from melting snow.

c. Recent Floods. Since 1927, five major floods, described below, have been experienced: March 1936, July 1938, August 1955, March 1968 and January 1979. Minor flood events have also occurred in November 1927, September 1938, September 1954 and October 1955. Table 8 lists the five greatest floods at selected USGS gages.

(1) The March 1936 flood, considered to be a single hydraulic event, actually occurred as two peaks of almost equal magnitude six days apart. At Woonsocket, a peak discharge of 14,200 cfs was recorded on 13 March and on 19 March a peak flow of 15,000 cfs was attained. The first peak was the result of a combination of rainfall and snowmelt, but the second was due to rainfall alone. Ground work for the flood was really prepared in December, when the temperature played a very important role. From December through February, the temperature was below normal, and a snow cover remained over the basin. As late as 9 March, the snow depth at Worcester was recorded as 10 inches, although most of the snow had disappeared by this time from the southern part of the basin, near Providence. Due to the low temperatures, thick ice covers were still on the ponds, lakes, and rivers. Even where ground surfaces were clear, the underlying soil strata were frozen preventing significant ground water percolation.

Beginning on 9 March and continuing through to 28 March, a period of abnormally high precipitation occurred throughout all New England, with the total rainfall for the month being twice the normal quantity. Although the major center of the first storm was in northern New England, a second center occurred in the lower Housatonic River basin in Connecticut. From 9 March to 13 March an average of 4 inches of rainfall per day fell in this area, with the maximum storm intensity recorded on 11-12 March. The second storm pattern was similar to the first. A secondary storm center occurred in the Blackstone basin at Worcester, where rainfall of 8.22 inches was recorded for 16-19 March.

TABLE 8

RECORDED FLOOD DISCHARGES

USGS Gaging Station	Drainage Area (sq. mi.)	Mar 1936 (cfs)	July 1938 (cfs)	Aug 1955 (cfs)	Mar 1968 (cfs)	Jan 1979 (cfs)
Kettle Brook Worcester, Mass.	31.3	2,520	880	3,970	1,400 (4)	1,700+ (4)
Quinsigamond River North Grafton, Mass.	25.5	-	-	820	452	652
Blackstone River Northbridge, Mass.	139.0	7,500	3,900 (2)	16,900	4,760	6,180
Branch River Forestdale, R.I.	93.3	5,800 (3)	3,950 (3)	4,240	4,980	5,470
Blackstone River Woonsocket, R.I.	416.0	15,000	15,100	32,900 (1)	15,400	16,100

(1) Affected by dam failure on Mill River. Flow without dam failure estimated to be 29,600 cfs

(2) Maximum average daily discharge

(3) Gage not established at this time - discharge value obtained by computation

(4) Estimated

High rates of runoff during this period of heavy rainfall resulted in the flood that crested on 19 March. The reduced rate of infiltration into the frozen soil mantle contributed to the production of runoff coefficients for the basin that were as high as 90 percent.

(2) During the period of 17-25 July 1938, an irregular series of showers and thunderstorms deposited widely varying amounts of rainfall over the eastern seaboard. Total precipitation exceeded 10 inches through eastern Connecticut and Massachusetts and northwestern Rhode Island. The individual storms within the 8-day period were not unusual, but the rapid sequence in which they succeeded one another prevented the streams from recovering during that intervening time. Consequently, the streams were pushed to successively higher stages in a series of peaks. Because of this series of rainfall events, numerous textile mills, homes and highways in the lower part of the Blackstone basin were flooded. This flooding was the highest flood on record until August 1955.

(3) The flood of August 1955, the maximum known to have occurred on the Blackstone River, produced peak discharges that were nearly twice the magnitude of any others experienced on this river. The flood resulted from record rainfall accompanying hurricane "Diane" falling on ground previously saturated by the precipitation of hurricane "Connie", which had occurred only one week earlier. Augmented by water released when the Horseshoe Dam on Mill River failed, the Blackstone River flow at Woonsocket, reached a peak of 32,900 cfs, 2.2 times the previous peak flow which occurred during the July 1938 flood. The maximum stage at Woonsocket, reached on 19 August 1955, was 7.4 feet higher than the maximum attained during the July 1938 flood. Storm rainfall in the watershed averaged approximately 13 inches. Total rainfall at Mendon, Massachusetts, was 13.7 inches with 5.2 inches occurring in a 2-hour period.

(4) The March 1968 flood produced a single peak discharge of 15,400 cfs on 19 March on the Blackstone River at Woonsocket. At this gaging station, the flood reached a maximum stage of 14.6 feet, slightly greater than the 14.4 foot stage of July 1938, and much less than the maximum stage of 21.8 feet recorded during the August 1955 event. Like the March 1936 flood, the March 1968 event was really the result of precipitation from the two storms. The first less intense storm occurred on 12-13 March. This rainfall together with snowmelt from scattered, sheltered, and wooded areas throughout the basin produced considerable runoff, filling ponds, lakes and reservoirs and contributing to local flooding. When heavy rainfall of the second storm fell on 17-19 March, the ground was fully saturated and surface water storage basins were full. Conditions were right for generation of the major flooding

that followed. Total storm rainfall over the basin during the period 17-19 March averaged about 5 inches.

(5) In January 1979, two separate severe storms, four days apart, each deposited between 3 and 4 inches of rain over the watershed. Runoff from these storms caused major flooding in some unprotected areas which experienced the highest water levels since August 1955.

6. EXISTING FLOOD CONTROL PROJECTS

a. Reservoirs. Subsequent to the August 1955 flood, the Corps of Engineers built the West Hill Flood Control Reservoir Project. Currently, there are no other flood control reservoirs in existence in the basin, nor are there any authorized.

West Hill Reservoir is located in the towns of Uxbridge, Northbridge and Upton, Massachusetts, with the dam proper located in Uxbridge on the West River about 3.2 miles above its confluence with the Blackstone River. The project, controlling 27.9 square miles, or approximately 80 percent of the West River watershed, serves principally to store flood waters providing stage reductions at downstream communities as far south as Pawtucket, Rhode Island. During normal riverflow the project also provides limited recreational opportunities. The Corps of Engineers has developed a public park within the project with facilities for swimming, picnicking and other related outdoor activities. Under an intensive management program, the Massachusetts Division of Fisheries and Game is developing the fish and game resources of reserved lands and waters.

The regulated storage capacity of the project is 12,400 acre-feet, with a surface area of 1,025 acres, equivalent to 8.3 inches of runoff from its intercepted watershed area. The dam is a 2,400 foot long, rolled, earth-filled structure with a dumped rock shell and has a maximum height of 48 feet above normal streambed. In addition, there are four earthen dikes totaling 1,200 feet in length with a maximum height of 19 feet. The project was completed in 1961. Its location is shown on plate 1.

b. Local Protection Projects

(1) Upper Woonsocket. An Upper Woonsocket local protection project was completed by the Corps of Engineers in 1959. This project was designed to protect an area of Woonsocket, along an 8,300 foot reach of the Blackstone River between the Massachusetts State Line downstream to South Main Street bridge, in Woonsocket.

The project affords complete protection to the area against floodflows equal to those experienced in the August 1955 flood (29,600 cfs) The project protects industrial properties in the city, as well as many homes, commercial establishments and extensive transportation facilities and public utilities. In addition, it reduces flood stages in the upstream communities of North Smithfield, Rhode Island and Blackstone, Massachusetts.

Major components of the project include channel improvements, construction of four dikes, a floodwall and pumping station, replacement of an industrial dam, underpinning and modification of two railroad bridges, relocation of a highway bridge, and relocation of four sewer siphons and two sewer lines.

Channel improvement included widening, deepening and straightening 6,700 feet of the river channel and constructing 1,600 feet of new channel at the Singleton Street bridge and downstream of the Fairmount Street bridge. The industrial area in the vicinity of Singleton Street is protected by 1,200 feet of earth dikes and 315 feet of concrete floodwall with a pumping station having a capacity of 33 cubic feet per second (cfs) handling the interior drainage during high river stages. The Woonsocket Falls Dam, formerly a fixed-crest masonry structure about 100 feet upstream of the South Main Street bridge was replaced by a 266-foot long concrete dam equipped with four tainter gates, each measuring 50 feet wide by 10.1 feet high. The piers of a railroad bridge at the lower end of the project area were underpinned and an existing trestle approach span was replaced by a new 50-foot plate girder span and abutment. A second railroad bridge located near River Street was also underpinned.

The city of Woonsocket assumed responsibility for the relocation of the highway bridge at Singleton Street, as well as all associated project utility revisions. It furnished lands, easements and rights-of-way; and maintains and operates the project as provided by law. Subsequent to the implementation of the project, the city replaced three other highway bridges over the Blackstone River.

(2) Lower Woonsocket. The Lower Woonsocket local protection project was completed by the Corps of Engineers in 1960. The project is located in Woonsocket along the Blackstone River and the tributaries, Mill and Peters Rivers. The project protects an area of the city downstream of the South Main Street bridge, supplementing the completed Upper Woonsocket protective works upstream.

The project consists of 4,950 feet of channel improvements along the Blackstone, Mill and Peters Rivers; 2,300 feet of pressure conduits on the two tributary rivers; alteration of utilities; and modification of the Bernon Street bridge to provide additional

channel capacity along the Blackstone River. It also affords protection to the Social and Hamlet districts of Woonsocket by 10,200 feet of earth dikes and concrete floodwalls with two pumping stations to handle the interior drainage during flood periods.

As modified by West Hill Reservoir in Massachusetts, the project was designed for flows equal to those of a standard project flood as follows: Blackstone River from South Main Street bridge to the confluence of the Mill and Peters Rivers 33,000 cfs, and 40,000 cfs for reaches below the confluence. Design flows on the Mill and Peters Rivers are 8,500 and 3,200 cfs, respectively. As designed, the project affords complete standard project flood protection to the industrial and commercial establishments and congested residential developments of the area.

c. Diversion of Floodflows. The Worcester Diversion Project, located in the towns of Auburn and Millbury on the south side of Worcester, was completed by the Corps of Engineers in 1960. It consists of a bypass for floodflows originating in the 30.1 square mile drainage area above the Leesville Pond diversion structures. These floodflows would otherwise transit the northward looping 7 miles of Kettle Brook, Middle River and the Blackstone River through heavily built-up Worcester.

The improvement includes a gated control dam across Leesville Pond, about 1.5 miles upstream and south of the existing Leesville Dam. Just upstream on the right bank, an ungated diversion weir and intake structure provide entrance to a 16-foot diameter, concrete lined diversion tunnel. The 4,205 foot tunnel runs southeasterly and empties into an 11,300 foot open channel which follows the general easterly alignment of Hull Brook to the Blackstone River. The improvement also included the construction of four new highway bridges, including one under I-290, and a railroad bridge across the open channel.

The project, operated and maintained by the city of Worcester, is designed for a flow of 6,000 cfs which is 75 percent of the standard project flood, or 50 percent greater than the record 4,000 cfs flood of August 1955. The Worcester Diversion provides significant reductions of floodflows through Worcester where heavy flood losses to industrial, commercial, residential, and public property have occurred in the past, particularly in 1955.

d. Others

(1) Federal

(a) Under the flood emergency provisions contained in Public Law 99, as enacted on 28 June 1955, emergency flood control

funds were provided following the March 1968 flood for the restoration of a flood control project along the westerly bank of the Blackstone River in Blackstone, Massachusetts between St. Paul Street bridge and the downstream railroad embankment. This former flood control project consisting of a stone masonry floodwall was originally constructed in 1936 under the Emergency Relief Act (ERA) for the protection of the town hall, courthouse building, residential homes and the town's recreational and athletic field. During the March 1968 flood, the original floodwall was fractured and collapsed into the river.

Project reconstruction was completed by the Corps of Engineers in 1971. The project includes about 1,025 linear feet of improvement consisting of 863 feet of earth dike, 162 feet of stone slope protection and appurtenant works. The project, as designed, affords protection for the August 1955 flood of 26,000 cfs which is about 87 percent of the standard project flood of 30,000 cfs.

(b) Disaster Relief Operation (DR) - Emergency funds were expended by the Corps of Engineers, following the August 1955 flood "Diane", to rehabilitate the deteriorated main stem channel conditions within the State of Rhode Island. Channel improvements involving removal of obstructions and sediment deposits were conducted for the following communities:

Towns of Cumberland and Lincoln

Removal of two islands and bridge obstructions which inhibited river flows.

Widening 1,900 linear feet of channel an additional 25 to 60 feet.

City of Central Falls

Removal of over 200 feet of sand and gravel bars and protruding boulders.

Widening 400 linear feet of channel an additional 20 feet.

Removal of rubbish and debris and clearing of trees and brush from riverbanks.

Removal of snags from the channel.

City of Pawtucket

Removal of rubbish and debris from riverbanks.

Removal of rock spur and snags from the channel.

Spoil areas were established for the removed materials with a considerable quantity of the excavated material utilized in the construction of temporary protective dikes.

(2) Non-Federal

(a) Commonwealth of Massachusetts - Subsequent to, and as a result of the severe damages experience in August 1955, the Massachusetts Department of Public Works, Division of Waterways, completed modification and restoration of numerous damaged projects within the Massachusetts portion of the Blackstone River watershed. A synopsis of completed work is as follows:

Worcester

Flood control work for Beaver Brook and Middle River to relieve flooding in Webster Square - project completed in August 1960.

Stream channel improvements and reinforced concrete box culvert along Mill Brook - completed November 1961.

Stream channel improvement along West Tatnuck Brook - completed May 1962.

Channel improvement at Marshall Pond and Mill Brook - completed November 1964.

Construction of reinforced concrete box culvert and incidental work along Mill Brook - completed July 1970.

Millbury

Channel improvements along Kitchen Brook and the Blackstone River in the upstream portion of the town of Millbury - completed prior to 1960.

Grafton

Channel improvement and diversion of the Blackstone River near Pleasant Street in the village of Saunderstown (Grafton) into two channels - the existing channel plus a new channel using the old Blackstone Canal alignment.

Northbridge

Reconstruction of Kupfer Dam - completed August 1958.

Stone slope protection work at Riverdale Street - completed April 1962.

Uxbridge

Reconstruction of Rice City Dam.

Supplementing the above projects, the Division of Waterways has also reconstructed, since the August 1955 flood, numerous bridges across the Blackstone River that were either destroyed or severely damaged. Channel improvements resulting from recent interstate highway construction near, and in the vicinity of, Worcester have also been completed.

(b) State of Rhode Island - Other than bridges reconstructed by non-Federal interests in conjunction with the two Woonsocket local protective works, no flood control projects have been undertaken or completed by the State of Rhode Island.

(c) Public - On 9 September 1972, the Blackstone River Watershed Association established "Project Zap" and launched the first of several phases of a massive clean-up campaign for the Blackstone River. On this day, "Project Zap" mobilized 10,000 volunteers to remove more than 10,000 tons of debris in a 14-mile reach of the Blackstone River from Pawtucket to the Woonsocket Falls Dam, and upstream of South Main Street Bridge in Woonsocket.

"Project Zap" is a first step in a continuing community effort for enhancing the beauty of the riverbanks and the river environment. The second phase, to be accomplished in the near future, would consist of the removal of silt and muck from the riverbed, thereby temporarily producing a more efficient hydraulic water course. Concurrent with this clean-up operation, a further thrust would be made to create and establish a series of ministrip or linear parks along the flood plain area of the river. This would inaugurate a series of recreational sites and areas to become the Interstate Park system and possibly a part of the National Recreational and Historic Parks managed by the US Department of the Interior. Such a bill was recently introduced in the US Congress by Representative Fernand St. Germain, 1st Congressional District of the State of Rhode Island.

7. FLOOD FREQUENCIES AND STAGE DISCHARGE RELATIONS

a. Discharge Frequencies. Peak discharge frequencies were determined by statistical analysis of the recorded annual peak flows at the six gaging station sites in the Blackstone basin. The frequency analysis was made using a Log Pearson Type III distribution in accordance with procedures described in Water Resources Council Bulletin No. 17A: "Guidelines For Determining Flood Flow Frequency". Weilbull plotting positions were used for plotting experienced data, and frequency curves were computed including expected probability and 95 and 5 percent confidence limits. The finally adopted skew for each site and resulting curve, was based on analysis of the computed curves, the plotted data, consideration of regional skews, and hydrologic experience and familiarity with the region.

The analysis and adopted curve for each of the six sites are graphically illustrated on plates 15 through 20. Recorded annual peak flows at the six sites are listed in table 9. For the Woonsocket statistical analysis, the data prior to 1960 was adjusted to reflect the present modifying effect of the West Hill Reservoir.

b. Discharge Frequencies at Index Stations. Discharge frequencies at selected index stations were determined by analyzing the adopted discharge frequency curves at gaging sites and developing relations between discharge frequency and drainage area for intervening index stations. Selected index stations and developed discharge frequencies for the mainstem Blackstone River are listed in tables 10 and 11. Similar analysis was also performed on the Branch River.

c. Rating Curves for Index Stations. Stage-discharge rating curves were developed at the established index stations as follows:

(1) For index stations at gage sites, information was obtained from the US Geological Survey.

(2) For index stations at dams, rating curves were computed using the basic broad crested weir equation with computations for both nonsubmerged and submerged conditions, where warranted.

(3) At other locations, ratings were developed by backwater computations. All ratings were checked against experienced high water levels and flows, where available. Adopted stage-discharge rating curves are shown on plates 21 through 34.

TABLE 9

RECORDED PEAK DISCHARGES
USGS GAGING STATIONS
(Discharge in cubic feet per second)

Water Year	Kettle Brook No. 1095	Northbridge No. 1105	Woonsocket No. 1125	Branch River No. 1115	Nipmuc No. 1113	Chepachet No. 1114
1924	740	xxxx	xxxx	xxxx	xxxx	xxxx
1925	450	xxxx	xxxx	xxxx	xxxx	xxxx
1926	400	xxxx	xxxx	xxxx	xxxx	xxxx
1927	230	xxxx	xxxx	xxxx	xxxx	xxxx
1928	790	xxxx	xxxx	xxxx	xxxx	xxxx
1929	473	xxxx	4,570	xxxx	xxxx	xxxx
1930	116	xxxx	1,970	xxxx	xxxx	xxxx
1931	935	xxxx	8,220	xxxx	xxxx	xxxx
1932	404	xxxx	4,530	xxxx	xxxx	xxxx
1933	586	xxxx	5,780	xxxx	xxxx	xxxx
1934	570	xxxx	6,560	xxxx	xxxx	xxxx
1935	1,020	xxxx	7,500	xxxx	xxxx	xxxx
1936	2,520	xxxx	15,000	xxxx	xxxx	xxxx
1937	429	xxxx	6,340	xxxx	xxxx	xxxx
1938	1,300	xxxx	15,100	xxxx	xxxx	xxxx
1939	337	xxxx	3,840	xxxx	xxxx	xxxx
1940	500	1,840	5,850	1,530	xxxx	xxxx
1941	219	1,560	4,480	1,480	xxxx	xxxx
1942	540	1,600	5,330	1,970	xxxx	xxxx
1943	237	1,600	5,310	2,120	xxxx	xxxx
1944	291	1,400	3,830	1,300	xxxx	xxxx
1945	312	1,440	3,410	1,160	xxxx	xxxx
1946	396	1,210	3,830	1,080	xxxx	xxxx
1947	213	1,480	3,150	782	xxxx	xxxx
1948	393	1,620	5,810	1,800	xxxx	xxxx
1949	162	768	2,030	532	xxxx	xxxx
1950	195	1,280	3,620	966	xxxx	xxxx
1951	596	2,270	4,920	1,370	xxxx	xxxx
1952	508	1,750	4,090	1,310	xxxx	xxxx
1953	584	1,860	5,570	1,260	xxxx	xxxx
1954	1,530	4,510	9,400	3,080	xxxx	xxxx
1955	3,970	16,900	32,900*	4,240	xxxx	xxxx
1956	852	2,830	8,710	2,550	xxxx	xxxx
1957	246	1,500	3,850	1,060	xxxx	xxxx
1958	687	2,120	4,980	1,590	xxxx	xxxx
1959	747	2,870	5,390	1,640	xxxx	xxxx
1960	580	2,520	5,500	1,470	xxxx	xxxx
1961	210	2,270	4,020	1,250	xxxx	xxxx
1962	270	2,620	5,790	1,170	xxxx	xxxx
1963	400	2,350	4,510	866	xxxx	xxxx
1964	195	1,670	5,520	1,500	xxxx	xxxx
1965	181	2,280	5,900	1,050	300	112
1966	115	1,620	2,280	742	150	148
1967	227	2,010	7,000	2,520	527	371
1968	1,100	4,760	15,400	4,980	1,020	1,080
1969	480	3,290	8,200	2,560	603	456
1970	360	3,470	8,100	2,780	742	553
1971	181	1,290	3,090	784	203	180
1972	640	2,820	8,290	2,470	550	384
1973	360	2,590	6,940	2,150	592	375
1974	200	2,210	5,920	1,790	501	428
1975	158	1,510	3,950	988	286	200
1976	154	2,840	9,130	2,780	600	Discont.
1977	220	1,770	4,590	1,440	305	xxxx
1978	93	1,560	9,010	2,590	632	xxxx
1979	258	6,190	15,900	5,470	1,840	xxxx

*Affected by the failure of Horseshoe Dam on Mill River

TABLE 10

INDEX STATIONS (BLACKSTONE RIVER)

Zone	State	River	Zone Extent	Index Station
0	MA	Kettle Brook	Stoneville Pond Dam to Worcester Diversion Structure (Sta. 2805+00 to 2742+40)	Worcester Diversion Structure (Sta. 2742+40)
1	MA	Kettle Brook	Worcester Diversion Structure to Curtis Pond Dam (Sta. 2742+40 to 2598+00)	Worcester Gaging Station (Sta. 2661+60)
II	MA	Middle River	Curtis Pond Dam to the former Middle River Bridge, Worcester (Sta. 2598+00 to 2515+00)	Former location of M.J. Whithall Assoc. Dam (Sta. 2535+00)
III	MA	Blackstone River	Middle River Bridge to Mouth of Hull Brook* (Sta. 2515+00 to 2331+50)	Worcester-Millbury Town Line (Sta. 2370+00)
IV	MA	Blackstone River	Mouth of Hull Brook to Millbury Woolen Mills Dam (Sta. 2331+50 to 2196+50)	Former location of Millbury Woolen Mills Dam (Hayward Schuster Dam) (Sta. 2196+80)
V	MA	Blackstone River	Millbury Woolen Mills Dam to Saundersville Dam (Sta. 2196+50 to 2043+50)	Saundersville Dam (Damaged) (Sta. 2043+50)
VI	MA	Blackstone River	Saundersville Dam to Mendon St. Bridge Uxbridge (Sta. 2043+50 to 1357+00)	Former location of Paul Whitin Dam (Sta. 1775+00)
VII	MA	Blackstone River	Mendon St. Bridge, Uxbridge to Blackstone Mfg. Co. Dam** (Sta. 1357+00 to 933+00)	Blackstone Mfg. Co. Dam (Tupper Corp. Dam) (Sta. 933+00)
VIII	MA RI	Blackstone River	Blackstone Mfg. Co. Dam to Hamlet Dam Woonsocket (Sta. 933+00 to 699+00)	Former location of Hamlet Dam (Sta. 699+00)
IX	RI	Blackstone River	Hamlet Dam to Valley Falls Dam, Valley Falls (Sta. 699+00 to 106+00)	Valley Falls Dam (Sayles Finishing Co. Dam) (Sta. 106+00)
X	MA RI	Blackstone River	Valley Falls Dam to Slater Mill Dam, Pawtucket (Sta. 106+00 to 4+00)	Old Slater Mill Dam, Pawtucket (Sta. 4+00)

*Downstream end of the Worcester Diversion Channel
**Known as the Blackstone Mill of the Lonsdale Co. (Tupper Dam).

TABLE 11

FLOW FREQUENCY (BLACKSTONE RIVER)

Zone		Drainage Area (sq. mi.)	Peak Discharges (CFS) (500 yr)	(200 yr)	(100 yr)	(25 yr)	(10 yr)	(2 yr)
0	Worcester Diversion Dam	30.0	8,000	5,350	3,900	1,850	1,150	400
I	Worcester Gaging Station	31.3*	1,050	650	420	150	80	20
II	Former Location of M.J. Whitall Assoc. Dam	50.0*	6,200	4,100	2,900	1,350	800	270
III	Worcester, Millbury Town Line	65.0*	8,900	6,000	4,300	2,100	1,300	460
IV	Former Location of Hayward Schuster Dam	78.0	14,900	10,300	7,600	4,000	2,600	1,020
V	Saundersville Dam	100.0	17,400	12,000	9,100	4,900	3,200	1,300
VI	Former Location of Paul Whitin Dam	138.0	21,400	15,000	11,500	6,400	4,200	1,800
VII	Tupper Corp. Dam	261.0**	32,000	22,800	18,000	10,500	7,300	3,300
VIII	Former Location of Hamlet Dam	369.0**	40,000	28,500	23,000	14,000	9,700	4,600
IX	Sayles Finishing Co. Dam	453.0**	46,000	33,000	27,000	16,400	11,600	5,650
X	Old Slater Mill Dam	478.0**	47,000	34,500	28,000	17,000	12,000	5,950

*Flow from approximately 30.0 square miles routed through Worcester Diversion
**Flow from approximately 33.0 square miles detained at West Hill Flood Control Reservoir

d. Stage-Frequencies for Index Stations. Stage-frequency curves for index stations were developed using the adopted stage-discharge and discharge-frequency relationships. Developed stage-frequency curves are shown on plates 35 through 48.

8. ANALYSIS OF FLOODS

a. General. The Blackstone River has been the subject of a number of hydrologic studies by the Corps of Engineers in the past, particularly as related to the planning design of the West Hill Reservoir and Upper and Lower Woonsocket local protection projects. These past studies involved in-depth analysis of past floods up to and including the major August 1955 event. Current studies principally involved supplemental studies of the more recent March 1968 flood and study of both the 1955 and 1968 floods on the Branch River. Past analysis of the August 1955 flood development in the basin is graphically presented on plate 49. An analysis of the 1955 flood and unit hydrograph development for the river at Woonsocket plus a summary of unit hydrographs for earlier floods are presented on plates 50 and 51, respectively. Supplemental unit graph analysis of the 1968 flood at Woonsocket is shown on plate 52, and analysis of the Branch River at Forestdale for both 1955 and 1968 events are shown on plates 53 and 54.

b. Flood Profiles. Flood profiles of recurring August 1955 and March 1968 floods were computed for both the Blackstone and Branch Rivers. A standard project flood profile was also computed for the main stem Blackstone. Profiles were computed using the computer program HEC-2, "Water Surface Profiles", developed at the Hydrologic Engineering Center, Army Corps of Engineers, Davis, California. Flood plain topography was obtained from an aerial photogrammetric survey of the mainstream of the Blackstone River dated May 1973, and from a prior report entitled "Flood Plain Information" - Blackstone River - Cumberland, Rhode Island - June 1971. Terrain data for the Branch River basin was taken from US Geological Survey maps. All data was supplemented by conventional ground surveys to determine elevations of river structures, channel cross sections and bridge openings. Channel sections used in the analysis were measured in the field at all river structures, and at intermediate points for long reaches of the river. Flows used in the analysis for the 1955 storm were obtained from past studies as illustrated on plate 49 with modifications for West Hill flood control reservoir and Worcester Diversion. Flows used in the analysis for the March 1968 storm were derived from recorded flows at Kettle Brook, Northbridge and Woonsocket. A discharge-drainage area relationship was established by plotting known information for the three gaging stations on log-log paper and fitting a curve to the three points. Flows at key locations along the river were then obtained by computing

the contributing drainage area at each point in question and reading the associated flow from the log-log plot. Similar drainage area - discharge relationships were developed for the Branch River relating flows to those recorded at the Forestdale gage. Discharges used in developing the profiles are listed in tables 12 and 13.

The flood plain shown on the Blackstone River plans represents those areas susceptible to flooding as a result of the 1955 storm of record and are plotted approximately using a contour interval of 5 feet. It is assumed no clogging of the bridge openings occurred. If clogging were to develop, river stages immediately upstream of the structures would rise.

A comparison of the recurring 1955 profile with the actual storm profile indicated the effectiveness of the flood control structures already in existence on the river. The stage had been reduced in the Worcester area by the Worcester flood control diversion and in the lower basin by the West Hill flood control reservoir. Local protection projects in Woonsocket confined recurring 1955 flow to the channel and eliminated considerable damage in that area.

9. STANDARD PROJECT FLOOD

a. General. Standard project flood discharges for the main stem Blackstone were determined in past studies, particularly in connection with the planning and design of the Lower Woonsocket local protection project and the West Hill flood control reservoir. The standard project flood was developed by applying standard project storm rainfall excess to developed unit hydrographs at gaging sites and ungaged locals, and then progressively routing the component hydrographs downstream. The standard project flood development for the Blackstone basin including adopted unit graphs is graphically illustrated on plate 55. The standard flood is shown at Woonsocket both with and without the effect of the West Hill project.

b. Standard Project Storm Rainfall. The standard project rainfall was based on criteria set forth in EM 1110-2-1411. Total 48-hour storm rainfall for the entire basin was 11.2 inches, with a maximum 24-hour amount of 9.6 inches. The maximum 6-hour amount was 7.4 inches. Maximum loss rates due to infiltration and other factors was assumed to be 0.1 inch per hour. Six-hour rainfall, losses and excess amounts are listed in table 14.

c. Flood Routings. Approximate coefficients for the progressive average-lag method of flood routing were developed for component routing in the Blackstone basin. Coefficients were based on analysis of historic floods with consideration of inflow and outflow of various reaches, distance of travel, and relative storage within the reaches.

TABLE 12

PEAK DISCHARGES FOR WATER SURFACE PROFILES
BRANCH RIVER BASIN

Location	Drainage Area (sq. mi.)	1968 (cfs)	1955 (cfs)
Branch River			
Junction w/Blackstone, Forestdale	93.2	5,059	4,307
#48 Forestdale Dam	91.2	4,960	4,240
#46 Slatersville (Middle) Dam	89.4	4,905	4,182
#43 Slatersville (Upper) Dam	85.8	4,755	4,066
#40 Mohegan Dam	72.2	4,188	3,629
#38 Glendale Dam	70.7	4,111	3,581
#37 Oakland Dam	66.0	3,868	3,429
Junction w/Chepachet	65.22	3,828	3,404
Pascoag-Clear River			
Junction w/Chepachet	44.02	2,529	2,404
#8 Harrisville Dam	41.3	2,372	2,135
#7A Graniteville Dam (Former)	22.5	1,258	1,132
#6 Premier Worcester Dam	12.4	659	593
#5 Green Shoddy Mill Dam	12.3	653	588
#4 Prendergast Mill Dam	12.1	643	579
#3 Wilson Res. Dam	11.7	622	560
Chepachet			
Junction w/Pascoag	21.2	1,299	1,000
#10 Mapleville Dam	20.0	1,225	943
#35 Gilleram Mill Dam	19.8	1,213	934
#34 Gazzaville Dam	19.3	1,183	911
(Gage @ Chepachet)	17.6	1,078	830
#33 Steere's Dam	17.4	1,066	821
#26 Valentine Mill Dam	12.2	748	576
#25 Mowry Dam	12.0	735	566
#23 Smith & Sayles Res. Dam	7.9	484	373
#22 Keech Pond Dam	6.1	474	365
Nipmuc			
Junction w/Pascoag	22.62	1,452	1,437
Nipmuc Dam (Proposed)	16.3	1,039	1,028
Nipmuc Gage	16.0	1,020	1,009

TABLE 13

PEAK DISCHARGES FOR WATER SURFACE PROFILES
BLACKSTONE RIVER BASIN

Location	1968 (cfs)	1955 (cfs)	SPF (cfs)
Stoneville Pond			
Worcester Diversion	1,100	3,500	7,700
Consolidated Rendering Company Dam	100	500	1,700
Small Weir	100	500	1,700
Worcester Electric Dam	100	500	2,500
American Steel & Wire, Dam No. 8	650	2,500	5,500
American Steel & Wire, Dam No. 9	650	2,500	5,500
N. E. Power Company	3,000	12,600	16,650
Sagdaw Storage Company Dam	3,000	13,600	16,800
Cenco Mills Dam	3,300	13,800	18,500
Saundersville Dam	3,700	14,000	18,500
Fischer Manufacturing Dam	4,400	16,200	19,500
J. J. O'Donnell	4,900	16,000	19,500
Duppfer Brothers Dam	4,900	14,800	20,900
Rice City Pond Dam	4,900	13,800	19,000
Tupper Dam	8,000	18,400	29,880
Saranac Mills Dam	11,600	21,500	34,760
Woonsocket Falls Dam	12,000	22,200	35,710
Manville Mill Dam	13,100	26,100	40,750
Berkshire Hathaway Dam	13,400	26,000	41,530
Ashton Fiberglas Dam	13,700	26,000	41,400
Pratt Dam	13,700	26,000	43,360
Sayles Finishing Company	14,800	25,700	43,070
Pantex Dam	15,300	26,700	43,290
Old Slater Mill Dam	16,000	26,700	43,000
BVG & E Company (Main St.) Dam	16,000	26,700	43,000

TABLE 14

STANDARD PROJECT RAINFALL
BLACKSTONE RIVER BASIN

Time (hours)	Rainfall (inches)	Losses (inches)	Excess (inches)
0	0	0	0
6	7.43	0.6	6.83
12	1.16	0.6	0.56
18	0.68	0.6	0.08
24	0.38	0.38	0
30	1.21	0.6	0.61
36	0.19	0.19	0
42	0.11	0.11	0
48	0.06	0.06	0
Total	11.22	3.14	8.08

FLOOD ROUTING COEFFICIENTS

Reach	Coefficients for 3-Hour Periods
Kettle Brook to Northbridge gage	7/2
Quinsigamond River to Northbridge gage	5/1
Northbridge gage to Woonsocket gage	15/5
Mumford & West Rivers to Woonsocket gage	11/4
Woonsocket gage to Pawtucket	7/2
West Hill Dam to Woonsocket gage	11/2

10. NIPMUC LAKE RESERVOIR

a. General. This proposed reservoir, on the Nipmuc River in the town of Burrillville, Rhode Island, would extend upstream across the Rhode Island-Massachusetts State Line into the town of Douglas, Massachusetts. The reservoir, as contemplated, would be a multi-purpose facility providing a degree of flood control along the Branch River and in the lower Blackstone River basin, and water supply for the northern area of Rhode Island. The dam would be a zoned rolled earth embankment, located approximately 0.8 mile above the confluence of the Nipmuc and Clear Rivers at Harrisville, Rhode Island. A concrete chute spillway is proposed on the easterly abutment with a control tower and operating gatehouse near the easterly abutment of the dam (see plate 56).

b. Spillway Design Flood Rainfall. The spillway design flood represents the most severe conditions of runoff that would result from probable maximum precipitation falling on ground saturated from previous rains. It was also assumed that the reservoir would be full to the elevation of the crest as a result of such previous rainfall (i.e. the top of the flood control pool). A discharge of 500 cfs through the flood control outlet was assumed during the routing computations to determine the spillway design discharge. Two types of spillway design floods were considered: (1) a summer-type flood with reservoir filled to the top of the flood control pool at crest elevation and (2) a spring-type flood involving snow-melt contributions with the pool at maximum water supply elevation. The summer-type flood was determined to be critical.

c. Probable Maximum Precipitation. Values of rainfall for the spillway design flood were obtained as Probable Maximum Precipitation from "Hydrometeorological Report No. 33 - Seasonal Variations of the P.M.P. East of the 105th Meridian", dated April 1956, as prepared by the Hydrometeorological Section of the US Weather Bureau. The adopted storm was adjusted to conform to this drainage basin. Losses from infiltration, surface detention transpiration and other tangible factors were assumed at a rate of 0.15 inch per 3-hour period which is consistent with minimum losses determined in previous studies for the New England area. Rates of precipitation, losses and rainfall excess as used in the selected storm pattern to compute spillway uesign flood inflow are shown in table 15.

d. Spillway Design Flood Hydrograph. The spillway design flood representing the inflow to a full reservoir is shown on plate 57. It was derived by applying the rainfall excess of table 15 to the developed unit hydrograph, shown on plate 58, plus a flow equal to the rate of rainfall on the 1.4-square mile reservoir water surface

area. An assumed base flow of 100 to 250 cfs was also added to the flood runoff. The peak of the spillway design flood inflow was 10, 121 cfs, equivalent to 679 cfs per square mile.

TABLE 15

PROBABLE MAXIMUM PRECIPITATION
(SPILLWAY DESIGN STORM)

Time (hours)	Rainfall (inches)	Losses (inches)	Rainfall Excess (inches)	Runoff Pattern (inches)
0	0.00	0.00	0.00	0.00
3	11.75	0.15	11.60	0.60
6	5.95	0.15	5.80	0.70
9	2.25	0.15	2.10	1.40
12	1.55	0.15	1.40	11.60
15	1.35	0.15	1.20	5.80
18	1.15	0.15	1.00	2.10
21	0.85	0.15	0.70	1.20
24	0.85	0.15	0.70	1.00
27	0.75	0.15	0.60	0.70
30	0.75	0.15	0.60	0.60
Total	27.20	1.5	25.70	25.70

e. Development of Spillway Surcharge - Length Curve. The spillway capacity was derived in accordance with established procedures, using the unit hydrograph and the synthetic storm of probable maximum precipitation, centered over the watershed. The spillway design floods were routed through the surcharge storage, assuming the outlet operative, to determine various lengths of spillway versus elevation (see plate 59). The selected length of spillway and corresponding surcharge was based on the most economical combination.

f. Spillway Site and Type. Selection of the zoned rolled earth fill dam embankment and topography of the site were the basis for selecting an uncontrolled overflow chute spillway. The spillway would be located on the easterly abutment and would be constructed as one monolith. The overflow section of the dam would be an ogee-shape crest, parallel vertical training walls to contain the flow and limit spray and a curved concrete chute discharge channel. To dissipate high discharge velocities, a stilling basin and riprap discharge channel would be provided.

g. Spillway Design, Size and Shape. The spillway would be a chute type, located on the southeast abutment. The weir would be an ogee section, straight in plan and founded on bedrock. The length of the spillway weir would be 60 feet at crest elevation, 401 feet above mean sea level. Height of the weir above the spillway approach would be 5 feet making the maximum elevation of the approach 396 feet mean sea level at the upstream face. The approach channel would slope toward the reservoir on a 1 percent grade for drainage. The concrete chute spillway, 1200 feet long, would return its discharges to the Nipmuc River through a tailwater channel excavated in the overburden. It was assumed that critical depth and velocity conditions would be attained just downstream of the crest centerline. It was estimated that the supercritical depth before the hydraulic jump on the chute having a 5 percent grade would be 1.83 feet with a velocity of 60+ ft/sec. The chute would be a smooth concrete channel with sidewall heights ranging from 15.0 feet at the crest to 5.0 feet at the start of the hydraulic jump. Maximum tailwater depth was calculated to be 20.0 feet; however, site conditions in the flat lowlands of the valley would produce a backwater condition at the dam with a water surface not exceeding elevation 345.0 msl, so that the change in stage of flow would probably occur at a lower elevation and downstream from the spillway toe. A 60-foot long stilling basin for energy dissipation would be provided at the terminus of the spillway. Beyond the stilling basin a 30-foot wide discharge channel would lead to the Nipmuc River (see "Inflow-Outflow Diagram", plate 60).

h. Storage Requirements.

(1) Flood Control. Flood control reservoirs in New England, constructed by the Corps of Engineers, generally have capacities equivalent to 6 to 8 inches of runoff from the contributing drainage areas. The exact amount of storage is dependent on the geographic location of the reservoir and physical limitations of the site. This amount of storage is required for effective control of the standard project flood and also for control of floods, the magnitude of such historical events as the August 1955 or more recently the March 1968 flood.

Hydrologic characteristics of the watershed dictated that at least 6 inches (5,200 acre-feet) of flood storage be recommended for authorization. Based on US Geologic Survey mapping of the area, the Nipmuc Project would provide flood control storage for 16.3 square miles of contributing drainage area, which represents approximately 3 percent of the entire Blackstone River basin at Pawtucket.

Natural discharge frequency curves were developed for the Branch and Blackstone Rivers (Woonsocket) gaging stations as well as the lower Blackstone River basin at Pawtucket. The Nipmuc Project would

reduce floodflows at Woonsocket by a 6 and 3 percent for the 1968 and 1955 floods, respectively. In a recurrence of these floods, the reservoir would generally reduce the flood stages at Woonsocket by 0.4 foot and would become progressively less downstream to about 0.2 foot at Old Slater Dam in Pawtucket. Area-capacity curves as well as reservoir storage capacities for Nipmuc Reservoir are shown on plates 61 and 62, respectively.

(2) Water Supply. For a "Development Plan for the Water Resources of Rhode Island", August 1967 by Metcalf and Eddy, Inc. to the Water Resources Coordinating Board, a plan was presented whereby a Nipmuc-Tarkiln Reservoir development would be considered. In this plan, the Tarkiln Reservoir would be constructed by the year 1990 and supplemented by flood skimming from a diversion structure at Nipmuc Reservoir. In 1995 the Nipmuc Reservoir would then be fully developed with transmission facilities to Tarkiln Reservoir and would produce an aggregate safe yield of 14 mgd.

This study, considered Nipmuc Reservoir as an alternate solution to the single purpose facility at the Nipmuc-Tarkiln sites. Growth figures developed by the Rhode Island Statewide Planning Agency to the year 2020 were used to select a yield of 10 mgd for the water supply component of a multipurpose reservoir. A yield of 10 mgd would require a reservoir storage of 11,500 acre-feet or the equivalent of 13.22 inches of rainfall on the watershed.

Monthly mean flow data was derived from the recordings of the Nipmuc River flow gage from the US Geological Survey. The station was established in March 1964 and data has been accumulated continuously to the present. Although the data is limited, it does reflect a recent drought period starting in April 1964 through February 1967. The data was adjusted for precipitation and evaporation and plotted as an accumulated mass inflow curve shown on plate 63.

(3) Low Flow Augmentation. An examination of the limited available records for the Nipmuc River gaging station indicates that the mean discharge for the lowest ten consecutive days, 3-12 September 1965, discharge was 0.59 cfs for the 16.0 square mile drainage basin. Although this is generally the method used to determine low flow releases, an adopted value of 0.2 cfs per square mile has been used. This would be equivalent to 3.0 cfs or 2.0 mgd.

(4) Dead Storage. A dead storage of 1,000 acre-feet (1.15 inches of runoff) with a pool elevation of 354.0 msl will also be provided. This storage will increase the head of the reservoir for water supply discharges as well as provide a sump area for collection of sedimentation accumulations.

i. <u>Evaporation on Proposed Reservoir Storage</u>. To estimate the evaporation losses from Nipmuc Dam Reservoir, evaporation maps from the US Weather Bureau Technical Paper 37, Washington, D. C. 1959 were used. The following pertinent data from this technical paper for the proposed site are as follows:

Surface area of reservoir (El. 385 msl) - 460 acres

Mean annual evaporation - 27.0 inches/year

Average May to October evaporation in percentage of annual - 75 percent, 20.25 inches

Plan evaporation factor - 0.70 to 0.80

Adopted year for analysis of evaporation - October 1964 to September 1965

Adopted total evaporation (an increase of 10 percent to account for water year 1965 - maximizing conditions) - 27.0 x 1.10 = 29.80 inches

Total precipitation on reservoir for water year October 1955 to September 1956 - 24.28 inches

Assuming 50 percent of this rainfall to be additional input on inflow, the net loss of evaporation:

29.80 inches - 12.14 inches = 17.67 inches = 676 acre-feet = 0.5999 mgd

Say 0.60 mgd

Consequently, during a dry year similar to October 1964 to September 1965, net evaporation loss will equal 0.60 mgd throughout the year.

j. <u>Sedimentation Effects on Storage Requirements</u>. Historically, loss of storage for the New England region, in general, has been a negligible problem. At Nipmuc Reservoir, the dead storage proposed is approximately 1,000 acre-feet, and the recreational storage, 3,900 acre-feet. Using an accepted rate of sedimentation for New England of 0.01 inch/year, calculations indicate that loss of the dead storage of 1,000 acre-feet, requires an erosion of 1.17 inches from the contributing watershed which would likely occur in a time period of greater than 100 years. Sedimentation, therefore, is not considered a significant factor in loss of storage.

k. Downstream Channel Capacities. Cross sectional areas and channel capacities, downstream from the dam are considered inadequate to provide desired emptying rates from the project. Since its establishment in 1964, the Nipmuc River gage has recorded discharges greater than 1,000 cfs (1968). Although no significant damage was reported in 1968 from the 1,000 cfs discharge, an adopted design emptying flow of 500 cfs, which represents a runoff rate of 30 cfsm, has been selected. To contain this design flow within the downstream channel banks, improvements will be needed from the dam site to Shipee bridge at Sherman Road.

l. Outlet Works.

(1) General. The outlet works for Nipmuc Reservoir will consist of separate flood control and water supply systems, with capacity of the outlets adequate to satisfy the following criteria:

Passing the required needs of water supply up to three times the maximum yield available (10.0 mgd x 3 = 30 mgd or 46 cfs)

Passing low flow discharges without interference to water supply (3 cfs)

Passing the 10-year frequency storm plus inflows during the construction period with 3.0 feet of freeboard for the construction cofferdam

Passing normal flows of the stream and safe channel capacities (500 cfs)

Permitting evacuation of the flood control reservoir (5,200 acre-feet) and inflow within 10 days and full reservoir within 25 days

Permitting evacuation of the water supply storage and inflow during 130 days.

(2) Outlet Works. The outlet works will be located approximately 700 feet west of the easterly abutment and will consist of an inlet channel, a control tower, a conduit under the dam and an outlet channel. Location of the outlet works is shown on the General Plan, plate 56.

(a) Inlet Channel. A 600-foot long channel of a uniform width will be excavated in earth, with bottom elevation at 334.0 mean sea level. The channel will be curved in plan.

(b) Control Tower and Operating House. The intake tower will house the flood control and water supply outlets. It will be a dry well type structure about 100 feet in height and will be located about 200 feet upstream from the centerline of the dam. A service bridge will provide access from the top of the dam.

The intake structure at the base of the tower will have an invert elevation of 339.0 feet msl and will consist of a 10-foot wide by 8-foot high trash bar structure, a rectangular entrance conduit 5-feet wide by 5-feet high with a vertical slide service gate and an emergency slide gate of the same dimensions. A vent pipe will be installed within the tower to satisfy the air demand at the service gate when operating at partial openings. Provisions will be included on the upstream face of the tower to permit lowering steel bulkheads for repair of the conduit or emergency slide gate.

The water supply outlet works will consist of four 2'-6"x3' screened inlets, controlled by 30-inch knife gates, discharging into a 48-inch diameter standpipe. Externally mounted slide gates will be provided at each intake for emergency closure. The vertical standpipe will discharge into a rectangular conduit at a point upstream from a 4 x 4-foot slide gate. The rectangular conduit will transition into a 36-inch diameter pipe leading to the treatment facilities. Centerline elevations of water supply inlets will be 390, 378, 366, and 356. Two cross connections between the 48-inch flood control outlet pipe and the 36-inch water supply discharge will be made. A 16-inch pipe with gate will be used to discharge low flow augmentation releases and a 36-inch line with gate will be used for emergency flood control or water supply.

The intake tower will contain three floors: (1) the heater room floor (elev. 404); (2) operating floor (elev. 417); and (3) the equipment room floor (elev. 432). The tower will house the hydraulic system for operation of the gates, a continuous water-stage recorder, an emergency generator, an overhead high lift crane, a forced warm air heating system and other appurtenant equipment. Electric power will normally be obtained from commercial sources. A metal spiral ladder will be provided for access to the lower tower for frequent inspection, servicing and operation of gates, valves, and pumps.

(c) Conduit and Transition. It is estimated that the rectangular conduits from the 48-inch diameter water supply standpipe and the flood control inlet will transition to circular sections within the limits of the control tower configuration. The control tower will be founded directly on bedrock.

(d) Outlet Channel. The outlet channel excavated in earth will be 30 feet wide and extend 700 feet to its junction with the spillway discharge channel. High velocities will require stone slope and bottom protection.

m. Freeboard. Freeboard refers to the difference in elevation between the maximum water surface and the top of the nonoverflow section of the earth embankment of the dam. A determination of wave height, run-up and wind setup followed the procedure outlined in Technical Memorandum No. 132 - "Waves in Inland Reservoirs". Winds producing the maximum waves and setup on the riprap slope of Nipmuc Reservoir dam would have to be aligned in a north-south direction due to the configuration of the water surface. Although it is unlikely that hurricane force winds would occur simultaneously with maximum reservoir surcharge, wind velocities of 70 mph across the water surface were selected for computation of the wave height and setup. A maximum effective fetch of 1.8 miles was used. Results indicated a significant wave height of 3.9 feet, a wave run-up ratio of 1.15:1.0 and a wind setup of 0.10 feet totaling 4.65 feet. A value of 5.0 feet was adopted as the minimum allowable freeboard.

n. Reservoir Regulation. Nipmuc River Reservoir will be regulated to reduce flows at downstream damage centers on the Pascoag, Branch and Blackstone Rivers. Outlet gates would be partially or completely closed whenever flood discharges were expected to exceed the downstream channel capacity, or when flood damages were anticpated. The reservoir will also be regulated in conjunction with West Hill Reservoir on the West River in southeastern Massachusetts to modify floods on the Blackstone River at Woonsocket, Cumberland-Lincoln, Central Falls and Pawtucket. Water supply capacity of the reservoir will be controlled to meet the needs of the anticipated users. As these needs increase, the manner of regulation will be adjusted. Under present conditions, downstream flows are not regulated by State law, however. a low flow release of 2.0 mgd exists. This flow is considerably greater than the natural flow for extended periods in dry years. In addition, downstream riparian and water right agreements will need to be satisfied.

11. HYDRAULICS OF LOCAL PROTECTION PROJECTS

a. Berkeley Local Protection Project

(1) Description of Improvements. The proposed Berkeley Local Protection Project would be located on the east bank of the Blackstone River, extending from river stations 280+00 to 320+00 in Cumberland. The project would include construction of about 5,000 feet of earth dike embankment and floodwalls, two railroad

gate structures, one highway gate structure, and one pumping station with appurtenant structures to be located just downstream from Martin Street bridge (see plate 64, and the Plan Formulation Appendix).

(2) Height of Protection. The project would be designed to protect against standard project flood levels in the river. Water surface profiles on the Blackstone River were computed for the SPF peaks using the computer program developed by the Hydrologic Engineering Center, Davis, California. A rating curve was developed for the Pratt Dam downstream from the site to obtain the starting elevation for the water surface profile for the design flood. From river stations 280+00 upstream to 320+00 water surface elevations range from elevations 75.0 to 84.5 In this reach, with the improvement in place, the river will be confined within the riverbank on the east bank and the Blackstone Canal bank on the west. Confining the flows caused the standard project water surface to rise from 81 feet NGVD to 84 at the upstream end of the project, an increase of 3 feet. Similarly, the August 1955 flood level would be increased from 77 to 78.5 feet NGVD at the upstream end of the project. However, it was found that the with and without project profiles would converge quite rapidly upstream of the project with the August 1955 flood profile reducing to a 0.7 foot difference about 2,000 feet upstream. The design water surface elevation was computed from backwater calculations using an "n" value of 0.030. Average velocities range from 14 feet per second downstream from the Martin Street bridge to 7 feet per second upstream at the upper end of the project. Losses through the Martin Street bridge were about 3 feet using contraction and expansion coefficients of 0.1 and 0.3, respectively. A minimum freeboard of 3 feet was used throughout the project. Plan and profiles of the project are shown on plate 65. Hydraulic computations were based on a minimum of cross section data and more detailed surveys and analysis would have to be made a part of any further design studies. The riverward slope of the dike would be riprap protected against flow velocities and the possible need for right bank protection would also be the subject of further study during any final design.

(3) Interior Drainage. The total interior area intercepted by the Berkeley Protection would be 270 acres. Of this total about 26 percent or 70 acres is the low level area lying west of the Providence-Worcester railroad. This low level area is below the design flood level of the river. The high level area is generally that area lying east of the railroad, is 200 acres in size and above the design flood level of the river. The interior area contains light to moderate development comprised of commercial, industrial or residential properties.

Runoff rates from the interior area were computed assuming hourly runoff equal to hourly rainfall, of varying frequencies as determined from US Weather Bureau Technical Paper No. 40, less an assumed loss rate of 0.1 inch per hour.

Elevation-storage data was computed for the interior area and levels A, B, and C established in accordance with EM 220-2-1410.

Ponding levels were then determined for a range of runoff frequencies and assumed discharge capacities as shown graphically on plate 66. Gravity discharge capacity and pumping station capacity were then selected based on potential damages, frequency of occurrence and overall project objectives. The selected gravity capacity was 530 cfs which would prevent 100-year frequency runoff from exceeding ponding level "A", elevation 65 feet NGVD. The selected pumping capacity of 180 cfs will maintain a 5-year frequency runoff, coincident with high river stage, within ponding level "B", and would maintain a 100-year storm runoff, coincident with high river stage, below level "C", elevation 69.5 feet NGVD.

Local officials would be charged with operating and maintaining the project. As part of the local assurances, 10 acre-feet of useable storage would be specifically preserved as ponding area below elevation 65 feet NGVD, no new development would be permitted in the protected area having first floor grades below elevation 69.5 feet NGVD and zoning would be enacted to prevent undue loss of existing storage capacity below elevation 69.5 feet NGVD. The operating floor of the pumping station would be at or above elevation 69.5 feet NGVD and equipped with two or more pumps so that the station would have two-thirds design capacity with one pump inoperable. Discharge lines from the station would pass over the dike and all gravity drains would be equipped with emergency gates on the riverward side of the dike.

An alternative interior drainage plan was studied but found more costly. It consisted of intercepting 150 acres of the high level drainage at three different points and conveying the runoff through the low area via two pressure conduits, one 42 inches in diameter and the other 72. This plan, would greatly reduce the drainage into the low level area but would not alleviate the need for a smaller capacity pumping station. This plan would have a pumping capacity requirement of 36 cfs to be comparable to the recommended plan having a pumping capacity of 180 cfs. The cost of the alternative pressure conduit plan was found to be about 85 percent more costly than the recommended plan.

b. Ashton Local Protection Project

(1) Description of Improvements. The plan of improvement at Ashton would be located on the east bank of the Blackstone River, extending from river stations 330+00 to 350+00 in Cumberland. The project would consist of about 2,000 feet of concrete floodwall, 400 feet of earth embankment dike, two railroad gate structures, and one pumping station with appurtenances (see plate 67).

(2) Water Surface Profiles. Design SPF water surface profiles for the project were computed using the "Backwater Computer Program" mentioned earlier in this report. A rating curve was developed for Pratt Dam downstream from the site to obtain a starting water surface elevation. From river stations 330+00 upstream to 350+00, water surface elevations ranged from elevations 84.5 to 89.0 msl assuming that dike protection had been provided at the Berkeley local protection project just downstream. In this reach, with the improvement in place, the river would be confined within the riverbanks on the east bank and the Blackstone Canal bank on the west. The design water surface profile was computed using a Manning's "n" coefficient value of 0.03. Average velocities ranged from 6 feet per second at the downstream limit of the project to 11.0 feet per second at the upstream limit near the Ashton Fiberglas dam. A freeboard allowance of 3 feet was used throughout the project.

(3) Interior Drainage. The protection at Ashton would intercept the runoff from 1,074 acres of interior area, with much of this area drained by Scott Brook. The interior drainage plan would convey Scott Brook, with a drainage area of 1,048 acres, through the protected area in a pressure conduit. The pressure conduit would be sized for a 100-year frequency runoff of 900 cfs based on the rational formula using a coefficient of 0.4. Runoff from the residual 26 acres would be allowed to pond to shallow depths (inches) during intense rainfall, but a small 20 cfs pumping station would be provided to prevent long term or accumulative ponding. An interior collector drain would be provided along the protection with capacity to convey the 10-year storm runoff. Gravity drains would be designed to discharge a 100-year storm runoff against normal river level.

12. HYDRAULICS OF DAM REPLACEMENTS

In an effort to reduce flood stages on the Blackstone River, analyses were made of possible modifications to and/or removal of existing dams located on the main stem of the lower Blackstone River in the vicinity of Pawtucket, Rhode Island.

a. Old Slater Mill Dam

(1) Description of Existing Dam. Old Slater Mill on the lower Blackstone River at Pawtucket, (see plate 68) is part of a historical site listed on the Federal Register (i.e. Slater Mill was the first successful cotton spinning mill in the United States). The dam is owned by the Blackstone Valley Electric Company and lies in the center of a highly industrial and commercial area. The east abutment of the dam appeared to be constructed on bedrock while the west abutment is an integral part of the supporting wall for the historic Slater Mill. For historic as well as aesthetic reasons, the dam should not be removed nor its upstream pool jeopardized as part of any proposal for reducing flood stages.

(2) Proposed Dam Modifications. The following modifications to Old Slater Mill Dam were considered in an effort to reduce flood stages on the Blackstone River:

(a) Diversion of floodflows over the easterly bank of the existing dam via a proposed conduit

(b) Lengthening the present crest from 176 to 250 feet

(c) Installation of bascule-type crest gates.

The effectiveness of these proposals on the March 1968, August 1955 and standard project floods are listed in tables 16, 17, and 18, respectively. While each modification had about the same effect on the August 1955 and standard project floods, the bascule gate modification was found to be most effective on the March 1968 flood and was therefore adopted. Under this proposal, the crest of the dam would be lowered 3 feet to elevation 21.08 feet NGVD and a bascule-type gate, hinged at the bottom on the modified crest, would be installed. At flood stage the gates would be automatically lowered to allow passage of high flows and in the closed position would maintain the upstream pool at its present elevation. The gates would be constructed in two leafs 88 feet long and operated hydraulically by level sensing equipment mounted on the westerly abutment.

(3) Crest Gates. The gates considered for this modification would be the "Pelican" style. The gates would be two leafs, 3'0" by 88'0", positioned on the lowered crest. The Pelican gate consists basically of a long leaf type structure hinged along its bottom edge and operated hydraulically. The gate operation is activated by a float sensor installed on the west abutment to measure upstream water levels. The leafs will be 3'0" high in order to maintain the original crest elevations (elevation 24.08 msl), but when activated will lower to a fully open position providing a modified

TABLE 16

1968 FLOOD - DAM IMPROVEMENTS

Description	Main Street Dam D/S	Main Street Dam U/S	Old Slater Dam D/S	Old Slater Dam U/S	Central Avenue D/S	Central Avenue U/S	Pantex Dam D/S	Pantex Dam U/S	Sayles Finishing D/S	Sayles Finishing U/S	Broad St. Bridge D/S	Broad St. Bridge U/S	Comments
Existing Conditions	24.76	29.10	29.66	31.67	34.99	35.02	35.02	42.52	50.53	57.81	57.77	57.82	
Scheme 1 Lower Old Slater Crest to El. 21.08	--	--	--	29.66	34.42	34.45	34.00	--	--	--	--	--	Reduces W.S. by 2.01
Scheme 2 Remove Pantex Dam	--	--	--	--	--	--	--	35.52	50.55	--	--	--	Reduces W.S. by 7.0'
Scheme 3 Lower Sayels Finishing Crest to El. 42.94	--	--	--	--	--	--	--	--	--	50.53	52.80	53.03	Reduces W.S. by 7.28
Scheme 1, 2, 3	--	--	--	29.66	34.42	34.45	34.00	35.52	50.55	50.53	52.80	53.03	Reduces W.S. @ O.S. 2.01, .57' @ Central Ave: 7' @ Pantex, 7.28' at Sayles Finishing
Scheme 4 600 SF Diversion At Old Slater Dam	--	--	--	30.52	34.42	34.45	34.00	--	--	--	--	--	Reduces 1.15' not effective
Scheme 5 (Scheme 1 & 4)	--	--	--	29.66	34.42	34.45	34.00	--	--	--	--	--	Same as Scheme 1
Scheme 6 Extend Crest of Old Slater Dam to 250'	--	--	--	30.67	34.42	34.45	34.00	--	--	--	--	--	Reduces 1.0' not effective
Scheme 7 (Scheme 1 & 6)	--	--	--	29.66	34.42	34.45	34.00	--	--	--	--	--	Same as Scheme 1

NOTE: "--" denotes El. remains as existing as indicated in Line 1.

TABLE 17

1955 FLOOD - DAM IMPROVEMENTS

Description	Main St. Dam D/S	Main St. Dam U/S	Old Slater Dam D/S	Old Slater Dam U/S	Central Ave. D/S	Central Ave. U/S	Pantex Dam D/S	Pantex Dam U/S	Sayles Finishing D/S	Sayles Finishing U/S	Broad St. Bridge D/S	Broad St. Bridge U/S	Comments
Existing Conditions	28.11	33.70	34.37	34.58	38.74	41.11	41.23	45.43	54.81	60.82	60.86	61.87	
Scheme 1 Lower Old Slater Crest to El. 21.08	--	--	--	34.37	38.68	41.04	41.17	--	--	--	--	--	Reduces W.S. by .21'
Scheme 2 Remove Pantex Dam	--	--	--	--	--	--	--	41.23	54.77	--	--	--	Reduces W.S. by 4.20'
Scheme 3 Lower Sayles Finishing Crest to El. 42.94	--	--	--	--	--	--	--	--	--	54.81	55.12	55.73	Reduces W.S. by 6.01'
Scheme 4 Scheme 1, 2, 3				34.37	38.68	41.04	41.17	41.23	54.77	54.81	55.12	55.73	
Scheme 5 Scheme 1, 2, 3 with Central Avenue Raised	--	--	--	34.37	38.68	38.83	38.99	38.99	55.00	55.00	55.21	55.80	
Scheme 6 600 sf Diversion at Old Slater Mill	--	--	--	34.37	37.78	40.28	40.58	--	--	--	--	--	Reduces Old Slater by .21', Pantex by 6.44', Sayles by 5.82'
Scheme 7 Extend Dam 250'	--	--	--	34.37	37.20	39.70	40.00	--	--	--	--	--	Same as Scheme 1

NOTE: "--" denotes El. remains as existing as indicated in Line 1.

TABLE 18

STANDARD PROJECT FLOOD - DAM IMPROVEMENTS

Description	Main St. Dam D/S	Main St. Dam U/S	Old Slater Dam D/S	Old Slater Dam U/S	Central Avenue D/S	Central Avenue U/S	Pantex Dam D/S	Pantex Dam U/S	Sayles Finishing D/S	Sayles Finishing U/S	Broad St. Bridge D/S	Broad St. Bridge U/S	Comments
Existing Conditions	32.63	32.63	39.60	39.60	45.21	50.68	51.68	51.68	59.48	64.68	64.68	67.96	
Scheme 1 Lower Old Slater Crest to El. 21.08	--	--	--	--	--	--	--	--	--	--	--	--	Not effective
Scheme 2 Remove Pantex Dam	--	--	--	--	--	--	--	51.68	59.48	--	--	--	Not effective
Scheme 3 Lower Sayles Finishing Crest to El. 42.94	--	--	--	--	--	--	--	--	--	59.48	59.48	50.14	
Scheme 4 Scheme 2 & 3	--	--	--	--	--	50.68	51.68	51.68	59.48	59.48	59.48	60.14	
Scheme 5 Remove Pantex plus Central Avenue	--	--	--	--	45.21	45.26	46.75	46.75	59.48	--	--	--	
Scheme 6 Extend Crest of Old Slater Dam to 250'	--	--	--	--									Not effective
Scheme 7 (Scheme 1 & 6)	--	--	--	--									Not effective

NOTE: "--" denotes El. remains as existing as indicated in Line 1.

crest elevation of elevation 21.08 to pass large flows. Fully open, the gate leaf rests on the dam crest and presents no obstacle to the flow. As floodwaters recede, the gates would automatically raise, thereby restoring the upstream storages.

(4) Approach Channel. The channel approaching the dam is relatively uniform in width with the bottom dropping 7 feet in approximately 4,000 feet from the Pantex Dam to Old Slater Dam. Leading to the dam, the river flows through the Central Avenue Bridge and the Exchange Street Bridge, then turns sharply, approximately 45° to the southwest as it approaches the dam. The low chord elevation (El. 37.4± msl) of the Central Avenue Bridge obstructs large flood flows. River bank elevations vary with retaining wall structures or industrial buildings aligning both banks. Both upstream and downstream river beds are ledge with little cover material and adjacent walls and buildings are supported on this ledge. Approach velocities for the 1955 flood flows range from 6 to 9 feet per second, under existing conditions, and change little with the dam crest modified to El. 21.08 msl.

(5) Downstream Channel. Downstream from the Slater Mill Dam on the east bank, the river is confined by new retaining walls for that reach from the dam to Main Street bridge. Top of wall elevations average 31.0± msl. The overbank area beyond the wall slopes steeply up to Broadway Avenue with grades ranging from elevation 50.0 to 36.0 msl at the bridge. The east abutment of the bridge is founded on bedrock and constructed of granite block. On the west bank, the west abutment of the Slater Dam is an integral part of the end wall of the Mill building. Just below the abutment, the tailrace from the mill complex discharges into the river (now inactive). Top of wall grades in this area average 26.0± msl. From this point, downstream to the Main Street bridge, the west bank is walled with top of wall grades of 31.0± msl. Overbank beyond the wall is a small grassed park area, with grades at elevation 28.5± msl.

The channel bed below the Old Slater Dam is bedrock with little overburden. This reach of the river diverges from a width of 200 feet at Old Slater Dam to an effective width of 100 feet at the Main Street bridge and dam, a distance of 375 feet.

At the Main Street Dam, the riverbed drops from crest elevation 17.0 to 9.0 msl. The dam and its abutments are constructed in bedrock and tied integrally with the bridge above. Main Street bridge is a two-span granite-faced arch bridge, with arches 50 feet in width and a crown elevation of 31.20 msl. From this point downstream, the river is tidal.

(6) Water Surface Profiles. Backwater computations were performed on the Blackstone River to show the effect of the proposed bascule gate modification at Old Slater Mill Dam. Profiles were computed for various floodflows coincident with the 100-year tide elevation, downstream of Main Street (see plates 69, 70 and 71). It was determined that for flows in excess of 30,000 cfs, the downstream hydraulic control becomes

the Main Street dam and bridge, which causes the existing Slater Mill Dam to become submerged. By lowering the crest of Slater Mill Dam 3 feet to elevation 21.07 feet NGVD and installing bascule gates, submergence would continue to occur; however, water surfaces elevations at the dam and upstream would be lowered as indicated in table 19.

TABLE 19

WATER SURFACE ELEVATIONS - OLD SLATER MILL

Q	Existing Crest Elevation 24.07		Modified Crest Elevation 21.07		U/S Differential
	U/S	D/S	U/S	D/S	
1968 - 16,000	31.67	29.66	29.66	29.66	2.01
20,000	32.83	31.52	31.52	31.52	1.31
25,000	34.17	33.66	33.66	33.66	.51
1955 - 26,700	34.58	34.37	34.37	34.37	.21
30,000	35.67	35.67	35.67	35.67	0.00

In addition, table 20 indicates that the modification to Old Slater Mill Dam would have little effect on existing channel velocities upstream or downstream of the dam.

TABLE 20

VELOCITIES

1955 Q (26,700)	Pantex Dam to Central Avenue	Central Avenue to Exchange Street	Exchange Street to Slater Mill
Existing (24.08)	7-9 ft/sec	6-12 ft/sec	6-9 ft/sec
Modified Dam (21.08)	7-9 ft/sec	6-12 ft/sec	6-9 ft/sec

b. Sayles Finishing Dam

(1) Description of Existing Dam. The Sayles Finishing Dam (formerly the Valley Falls or Samoset Dam) built in 1853-54, is a masonry arch dam located on the Blackstone River approximately 80± feet downstream from the Broad Street bridge in Central Falls, Rhode Island (see plate 72). Field observations, as well as reference plans and records, indicate the dam to be an arch-gravity type construction bearing on bedrock, approximately 187 feet arc length with a masonry

thickness at the crest of about 9 feet. Examination of the abutments coupled with the shallow arch of the dam indicates the structure gains its stability through its mass gravity section rather than transmitting any significant thrust to the abutments. Records indicate the upstream face is of granite. Upper portions of this face appear to be quarried cut stone in fixed courses, while lower reaches of the dam are of quite irregular field stone. Appurtenant to the dam proper on both banks upstream, sluice gates were built to divert the Blackstone's waters into adjacent mill complexes. The dam, and abutting property as well as water rights, are at present part of the estate of the Sayles family.

A condition survey to examine the present state of the existing dam was beyond the scope of this phase of the study; however, future design phases must investigate, in detail, the structural integrity of the dam as well as its ability to sustain increased loads and thrusts from the installation of crest gates.

Channel improvements in the lower Blackstone River basin considered the replacement of this dam with a gated structure.

(2) Description of the Proposed Structure. It is proposed to replace the upper portions of this dam with water control type gates, such that in the closed or normal position the crest of the dam would reamin at its present crest elevation. During flood stages, the gates would be opened, reducing the upstream water surfaces. The communities of Lincoln, Cumberland and Central Falls, in conjunction with the State of Rhode Island, have proposed a conservation-recreation area for the Valley Falls Pond upstream from the dam, hence installation of a gated dam would maintain present water levels, reduce flood stages, and be consistent with this planning.

The crest of the existing dam elevation 49.94 msl would be lowered to elevation 42.94, the upstream average bed elevation, and hinged crest bascule gates 7 feet high installed. Three leaf-type gates, 60 feet in length, hinged along their bottom edge and operated hydraulically would be constructed on the reduced crest. The gate would be automatically controlled by means of a level sensing device in order to be fully open as floodwaters increase, but still maintain upstream storages under nonflooding conditions.

(3) Proposed Crest Gate. For this proposed installation, the crest gate would be the "Pelican Gate" style as manufactured by Allis-Chalmers. The gate would be in three 60'0" sections placed as chords across the lowered crest of the dam (elevation 42.94). The Pelican gate consists basically of a long, leaf-type structure hinged along its bottom edge. The hinged edge is attached to the crest of the dam and operated by hydraulic cylinders. The gate

regulator is controlled by a float actuated sensing device to position the gate properly for upstream water level conditions. The leafs will be 7'0" high and when closed, the original crest elevation of 49.94 msl will be maintained. Once the hydraulic head on the dam actuates the regulator, the gates will open incrementally and be fully open for floodflows so that the crest elevation will be 42.94. In open position, the gates lie flat on top of the dam to become part of the spillway with no obstacle to the passage of floodwaters. As floodwaters recede, the gates are raised and increase the effective height of the dam. Controls for the gates operation would be installed in a metal enclosure on an abutment protected by fencing.

(4) Approach Channel. The approach channel leading from Valley Falls Pond is approximately 1,300 feet long and relatively uniform in width with a straight approach to the dam. On the south bank, the terrain is quite steep with top of bank elevations of 90.0± with the exception of that area immediately upstream from the Broad Street bridge.

On the north bank, grades range from elevations 60 to 70.0 msl. Upstream from the Broad Street bridge approximately 300± feet, the Blackstone Valley Sewer Commission has a trunk sewer line crossing the channel. Leading from a sewer gaging chamber on the north bank, two subaqueous pipes (one 18-inch and one 24-inch pipe) cross to the south bank siphon outlet chamber. Available plans indicate both pipelines lie 2 feet below river bottom with their low point at approximately elevation 30±.

The Broad Street bridge, a granite faced 3-span arch bridge, lies approximately 80± feet upstream from the Sayles Finishing Dam. Field survey indicates the arches to be 62.0± feet wide with a crown elevation of 62.0. Appurtenant to the dam proper on both banks upstream, sluice gates were built to divert Blackstone's waters into adjacent mill complexes. It appears that at present, both gate structures are slightly open to equalize hydrostatic pressure and reduce the loads carried by these structures. Elevations of both structures are approximately 59.0±. At present, approach velocities ranging from 6 to 8 feet per second under existing conditions will be increased to 10 to 12 feet per second for a flood equal in magnitude to the storm of record (1955) with the lowered crest and gates fully open. With no modifications to Sayles Finishing Dam, Broad Street bridge starts to raise upstream water surface elevations above flows of 30,000 cfs.

(5) Downstream Channel. Record drawings indicate that the downstream face of the dam varies in height from 10 to 24 feet. Inspection of the dam by "Jencks and Ballou" in 1952 revealed two large

"holes" in the river bed just downstream from the dam and that further downstream the river bed was exposed bedrock. The Providence and Worcester Railroad Company tracks cross the Blackstone River 400 feet below the dam. The three-span structure supports two lines of tracks. The piers are granite-faced with the northerly pier on the island formed by the north bank of the main stream and the northern tailrace while the southern pier was constructed at the midpoint of the river. Low chord elevation of the supporting plate girder is 62.82.

(6) Water Surface Profiles. The results of backwater computations illustrated in tables 16, 17, 18 and 21; and plates 69, 70, and 71, indicate that reducing the crest is an effective means of reducing upstream water surface elevations at the site. It was found that removal of Pantex Dam further downstream from the Sayles Dam has little or no effect on water surfaces above Sayles Finishing Dam. In addition, for discharges more than 30,000 cfs, the railroad bridge immediately downstream from the dam as well as Broad Street bridge just upstream of the dam affect the upstream water surface elevations under the existing conditions; however, when the crest is lowered by 7.0 feet, the hydraulic controlling effect of these two structures is decreased. With Sayles Finishing Dam lowered by 7.0 feet, the comparative water surface elevations are listed in table 21.

TABLE 21

WATER SURFACES - SAYLES FINISHING DAM

Q in cfs	Upstream Water Surface Existing Crest	Upstream Water Surface 7.0 foot Lower Crest
1968 - 16,000	57.81	50.53
1955 - 26,700	60.82	54.81
SPF - 43,500	64.68	59.48

Replacement of the Sayles Finishing Dam with a gated structure will reduce the August 1955 flood stage approximately 6 feet upstream. To protect all riverbank property upstream, a 300-foot dike would need to be constructed on the south bank immediately above the Broad Street bridge. With a 3-foot allowance for freeboard, the top of dike would be at approximately elevation 57.5. Reducing the crest elevation has no effect on downstream water surface elevations, however backwater computations for the 1955 flood for the downstream reach between the Providence-Worcester railroad tracks and the Sayles Dam indicate water surface elevations ranging from elevation 51 below the bridge to elevation 55 above the bridge to the dam. Existing bank elevations are approximately 70 on the north bank along Mill Street and 41 to 45 on the

on the south bank and would require dike protection. Water surface elevations downstream are affected by the restrictions of the railroad bridge for flows greater than 30,000 cfs.

(7) Affected Bridge Piers and Abutments. As mentioned previously, the Broad Street bridge is 80 to 100 feet upstream from the dam site. Plans and records of its construction are not available; however, it appears to have granite-faced piers to an unknown depth. The presence of rock outcroppings in the area would indicate that the foundations are probably founded on ledge. Both abutments and piers would need to be protected from high velocity flows. Resulting velocities from modifying Sayles Finishing Dam for the 1955 flood are approximately 11 feet per second at the bridge. Four hundred feet downstream from Sayles Finishing Dam, the Providence-Worcester railroad bridge piers and abutments would need to be protected from 1955 flood velocities of 6 to 7 feet per second.

(8) Modification of Dam and Its Effect on Velocities and Scour. Modification of Sayles Finishing Company Dam has no effect on downstream velocities. Table 22 indicates resulting upstream velocities.

Granite-faced retaining walls protect the upstream banks from scour in that reach from the Sayles Dam to Broad Street bridge. Unprotected banks upstream from Broad Street bridge will have resulting velocities from the 1955 flood stages of approximately 3.0 feet per second and should not effect the existing bank material or the subaqueous sewer crossing.

TABLE 22

UPSTREAM VELOCITIES (Ft/Sec)

Event	Existing	Modified
1955 Storm Q = 26,700 cfs	5-7	11-12
1968 Storm Q = 14,800 cfs	4-5	10-13
SPQ Q = 43,100 cfs	4-9	7-11

(9) Impact on Existing Sediments. No subsurface explorations were undertaken during this study to ascertain the quantity of upstream sediments trapped behind the present dam. However, a "Report on the Samoset Dam of the Blackstone River at Broad Street Bridge", by Jencks and Ballou in September 1952, refers to several photographs taken in 1940, when the upstream pool level was lowered; these show that the

exposed upstream face of the dam is approximately 6 to 9 feet high (vertically) from the then existing ground surface to crest. Levels by Jencks and Ballou at the time of their report (1952) were consistent with these dimensions, indicating little build-up of sediments. However, it is believed that at the time of the construction of the Broad Street bridge upstream about 50 or more years after the present dam construction took place, some stone and debris was deposited against the upstream face of the dam. Undoubtedly the present dam has trapped some sediments against its upstream face, overlying this material. Any construction, particularly lowering of the crest, dewatering or bypassing flows, will release some of these deposits. It can be assumed that the 1955 and 1968 floodflows scoured upstream sediments from ponds (Valley Falls, Scotts and New Pond) as well as upstream river reaches and transported some of these sediments to the Sayles Finishing Dam. During the modifications of the existing dam, some removal of upstream sediments must be undertaken.

13. REMOVAL OF PANTEX DAM

a. Description of Existing Dam. Pantex dam, an "L"-shaped gravity type structure, is located in downstown Pawtucket on the main stem of the Blackstone River, midway between the Roosevelt and Central Avenue bridges. Its construction allowed the Blackstone's waters to fill the headraces of the Pantex Mill complex on the west bank of the river. The dam at elevation 34.92 msl and with crest length of 238 feet is a stone masonry structure similar to the Sayles Finishing Company Dam and others constructed in the 1800's. A gate house, constructed on the east bank, forms the east abutment of the dam. At dam crest (which is elevation 34.92) the downstream bed elevation is 22.0 msl, while upstream bed elevations are about 27.5±.

b. Description of Proposed Structure. An analysis was made to determine the effects of removing the Pantex Dam structure. Analysis indicated that lowering the crest elevation of Pantex Dam greater than 7.0 feet was noneffective since submergence occurs and downstream water surfaces control resulting upstream water surface elevations at that point. Hence, removal of the dam will be considered to a maximum of 7.0 feet only.

c. Approach Channel. Pantex Dam is located about 500 feet downstream from the Roosevelt Avenue bridge at a sharp 90 degree bend in the Blackstone River. Above the bend at the bridge, river widths are approximately 200 feet, while at the dam they are 150 feet. Above the dam north bank elevations range from 50.0 to 60.0 along Japonica and Middle Streets, while on the south bank, highest elevations are 40.0, adjacent to the former mill complex. Roosevelt Avenue bridge is a three-span granite arch structure, with spans approximately 60.0 feet in width and crown elevations 50.15 msl. The southernmost arch has

a shallow riverbed forcing most streamflow through the two northern arches. Approach velocities for existing conditions range from 7 to 10 feet/second, and with the dam crest removed to elevation 27.92 msl, they increase from 7 to 15 feet/second.

d. Downstream Channel. Below Pantex Dam, the Blackstone River is generally uniform in width downstream to the Slater Mill Dam area, a distance of approximately 4,000 feet. The riverbed drops from elevation 22.0 msl at the downstream face of Pantex Dam to about 15.0 at Old Slater Mill Dam, a relatively flat slope. Through this reach, the river flows through the Central Avenue bridge in Central Falls and further downstream the Exchange Street bridge, in Pawtucket. The Central Avenue bridge has two 78-foot spans with a center pier at the midpoint of the river. The roadway has a low chord elevation 37.35, which obstructs larger flood stage flows. The Exchange Street bridge is a two-span arch with openings 81.0 and 99.0 feet wide, respectively. Crown elevations of the arches are 47.64, well above flood stage. The east bank on the river through this reach averages elevation 40.0 msl with several large manufacturing plants abutting the river. On the west riverbank, grades average elevation 30.0 msl with commercial and industrial properties fronting on the river's edge. Tailwater velocities for 1968 floodflow magnitudes remain unchanged at 6 to 8 feet/second, with Pantex Dam in place or removed. Flows equal in magnitude to the 1955 storm generate tailwater velocities of approximately 7 to 9 feet/second, with the dam intact or removed. If the Central Avenue bridge were to be raised, removing the downstream restriction, the velocities would increase to 8 to 10 feet/second.

e. Water Surface Profiles. Analysis of this dam indicates that the existing crest becomes submerged at approximately 40,000 cfs; therefore, it has a direct influence on upstream water surface elevations for lesser flows (see table 23). Removal of more than 7.0 feet of the dam crest serves no purpose, for downstream water surfaces. However, as demonstrated in table 23, reductions of upstream water surfaces from 7.5 feet for the 1968 recurring flood to 1.27 feet for a flow of 35,000 cfs, respectively, can be achieved if the dam is modified. In addition, loss of head at the Central Avenue bridge is causing water elevations to rise downstream of Pantex Dam.

Backwater computations also indicate that upstream water surface elevations are lowered by removal of Pantex Dam only in that reach from the dam to the Roosevelt Avenue bridge. Channel restrictions below the bridge tend to maintain high water surface elevations at the downstream face of Roosevelt Avenue bridge negating the effects of removing Pantex Dam (see table 24).

TABLE 23

WATER SURFACE ELEVATIONS AT PANTEX DAM

Q (cfs)	Existing Crest (El. 34.92) U/S	Existing Crest (El. 34.92) D/S	Reduce Crest (El. 27.92) U/S	Reduce Crest (El. 27.92) Reduct.	Reduce Crest to 27.92 and Raise Central Avenue U/S	Reduce Crest to 27.92 and Raise Central Avenue Reduct.
1968-16,000	42.52	35.02	35.52	-7.00	35.02	-7.50
20,000	43.78	36.56	36.56	-7.22	36.36	-7.42
25,000	45.02	40.29	40.29	-4.73	38.37	-6.65
1955-26,700	45.43	41.23	41.23	-4.20	38.99	-6.44
30,000	46.24	43.24	43.24	-3.00	40.32	-5.92
35,000	47.38	46.11	46.11	-1.27	42.19	-5.17
40,000	48.72	48.72	48.72	0	43.95	-4.77
SPF -43,500	51.68	51.68	51.68	0	46.75	-4.93

TABLE 24

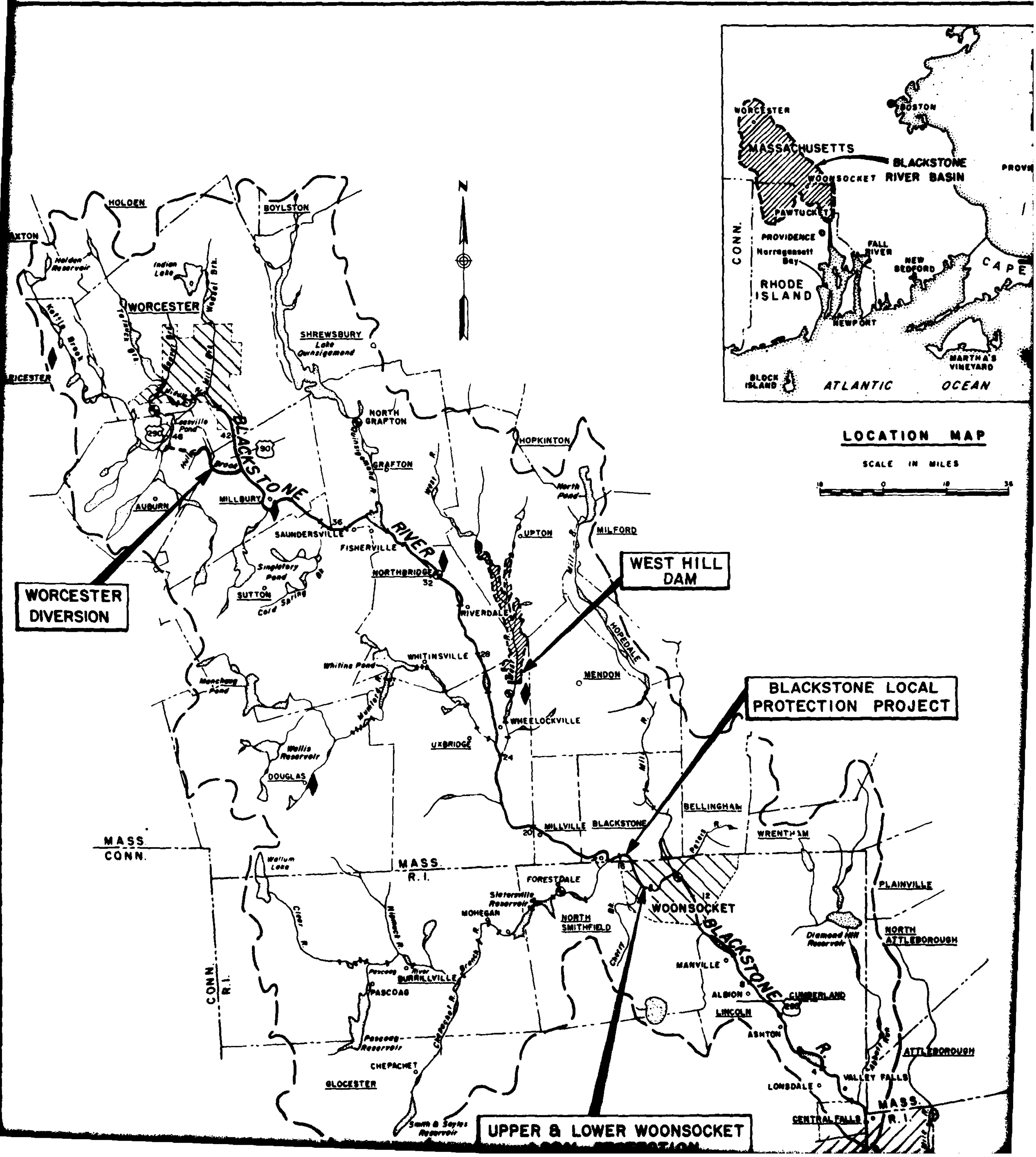
WATER SURFACE ELEVATIONS U/S OF PANTEX DAM

Q(cfs)	(Existing) Pantex Dam U/S	Removed (Pantex Dam) U/S	Removed (Pantex Dam) Raised Central Ave. U/S	Roosevelt Avenue Bridge D/S	Roosevelt Avenue Bridge U/S
1968	42.52			43.45	43.48
1968		35.52		43.37	43.41
1968		35.52	Not effective	--	--
1955	45.43			46.65	46.75
1955		41.23		45.46	45.58
1955		41.23	38.99	46.87	46.97
SPF	51.68			51.85	55.02
SPF		51.68		51.85	55.02
SPF		51.68	46.75	49.10	49.40

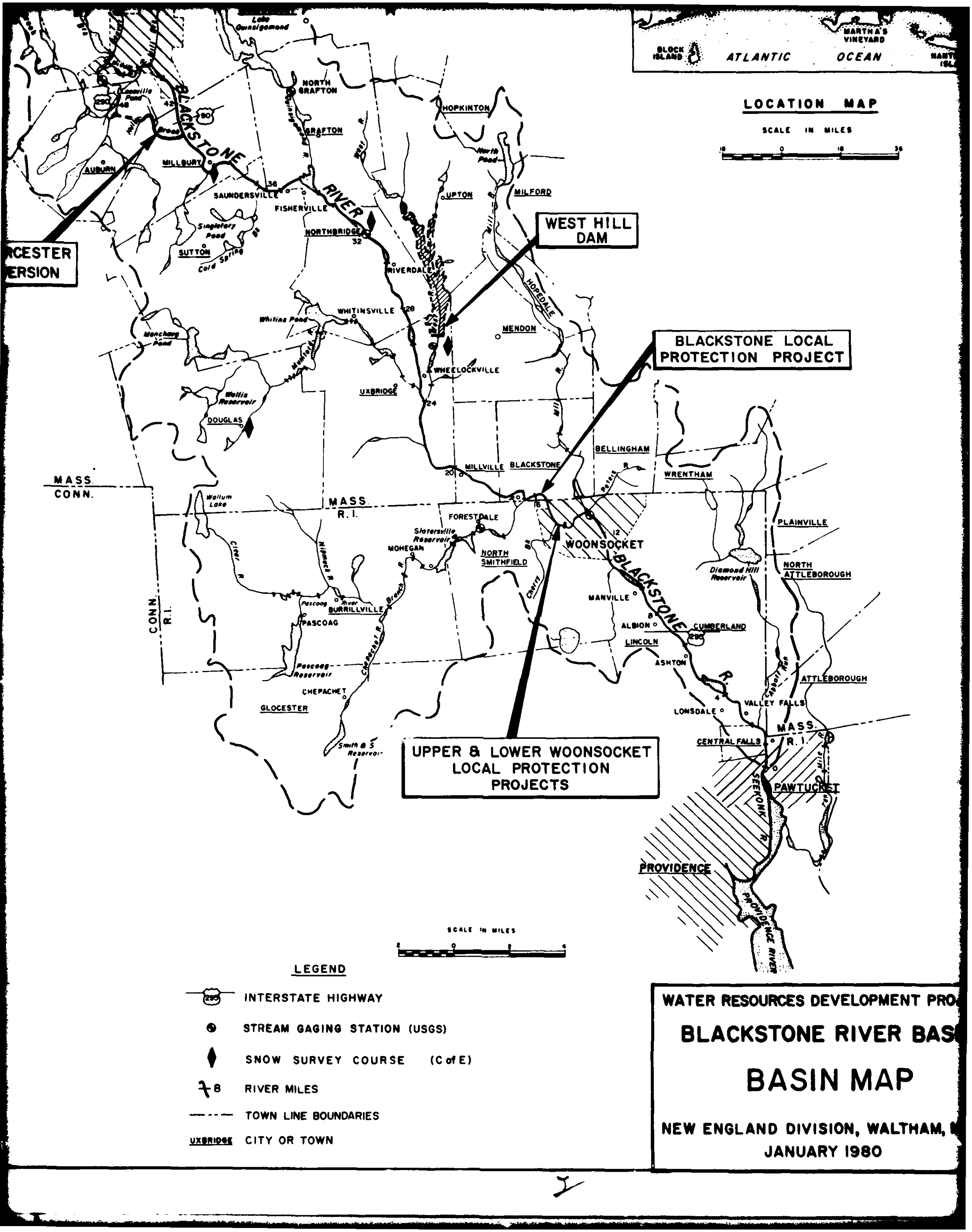
Table 24 also indicates the results achieved in the reduction of water surface elevations for removal of Pantex Dam and removal of Pantex Dam in conjunction with the raising of the roadway deck of the Central Avenue Bridge above the anticipated water surfaces.

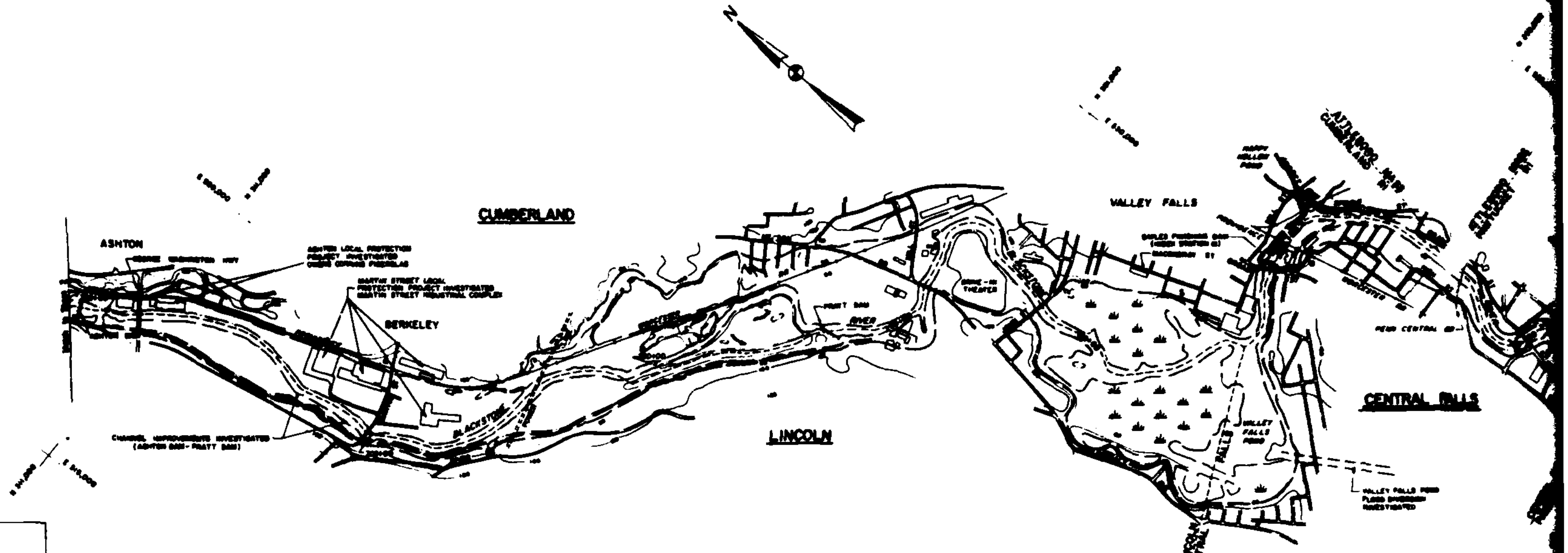
f. Affected Bridge Piers and Abutments. Using the August 1955 storm of record as the design storm, existing channel velocities at Roosevelt Avenue bridge of 7 feet/second occurred with the dam in place or removed. With Central Avenue bridge raised above the floodway and the Pantex Dam modified, channel velocities remain at 7 feet/second.

g. Impact on Existing Sediments. Field survey indicates that riverbed elevations immediately upstream from the dam average 27.0$\pm$. With removal of the upper portions of the dam to elevation 27.92$\pm$, sediments transported to and deposited against the upstream face should not move. However, with the modification to the dam crest elevations, velocities will increase from 10 to 15 feet/second and upper layers of the trapped sediments will be scoured away.

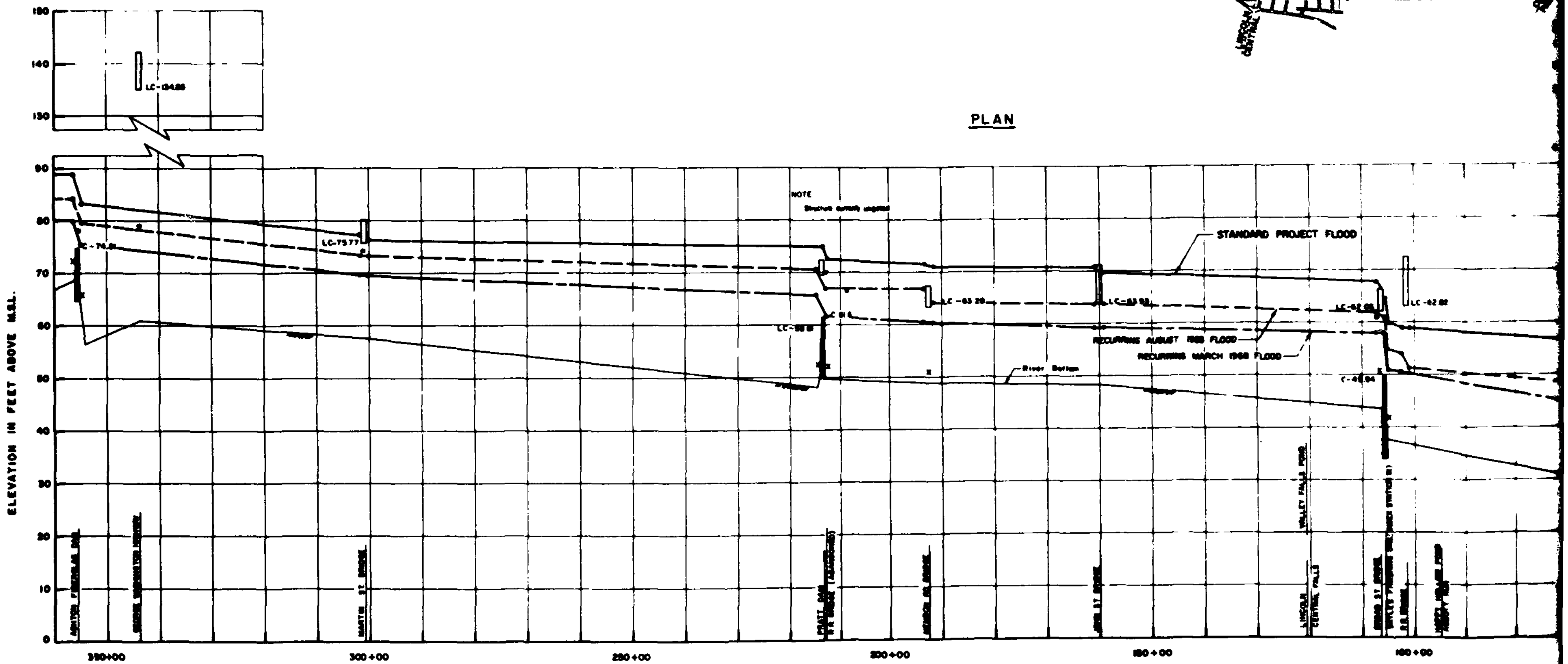


LOCATION MAP
SCALE IN MILES
WORCESTER
MASSACHUSETTS
BLACKSTONE RIVER BASIN
BOSTON
WOONSOCKET
PAWTUCKET
PROVIDENCE
CONN.
RHODE ISLAND
FALL RIVER
NEW BEDFORD
NEWPORT
MARTHA'S VINEYARD
BLOCK ISLAND
ATLANTIC OCEAN
CAPE
WORCESTER DIVERSION
WEST HILL DAM
BLACKSTONE LOCAL PROTECTION PROJECT
UPPER & LOWER WOONSOCKET
HOLDEN
BOYLSTON
SHREWSBURY
Lake Quinsigamond
Indian Lake
Holden Reservoir
WORCESTER
Kettle Brook
NORTH GRAFTON
GRAFTON
HOPKINTON
North Pond
MILLBURY
AUBURN
SAUNDERSVILLE
FISHERVILLE
BLACKSTONE RIVER
NORTHBRIDGE
UPTON
MILFORD
Singletary Pond
SUTTON
Cold Spring Bk.
RIVERDALE
HOPEDALE
WHITINSVILLE
Whiting Pond
Manchaug Pond
MENDON
WHEELOCKVILLE
UXBRIDGE
Wallis Reservoir
DOUGLAS
BELLINGHAM
MILLVILLE
BLACKSTONE
WRENTHAM
MASS.
CONN.
R.I.
Wallum Lake
FORESTDALE
Slatersville Reservoir
MOHEGAN
NORTH SMITHFIELD
WOONSOCKET
PLAINVILLE
Diamond Hill Reservoir
NORTH ATTLEBOROUGH
Clear R.
Pascoag River
BURRILLVILLE
PASCOAG
Pascoag Reservoir
CHEPACHET
GLOCESTER
Smith & Sayles Reservoir
MANVILLE
ALBION
CUMBERLAND
LINCOLN
ASHTON
BLACKSTONE R.
ATTLEBOROUGH
VALLEY FALLS
LONSDALE
CENTRAL FALLS


ATLANTIC OCEAN
BLOCK ISLAND
MARTHA'S VINEYARD
LOCATION MAP
SCALE IN MILES
WEST HILL DAM
BLACKSTONE LOCAL PROTECTION PROJECT
UPPER & LOWER WOONSOCKET LOCAL PROTECTION PROJECTS
RCESTER
ERSION
BLACKSTONE RIVER
BLACKSTONE R.
NORTH GRAFTON
GRAFTON
HOPKINTON
MILLBURY
AUBURN
SAUNDERSVILLE
FISHERVILLE
NORTHBRIDGE
UPTON
MILFORD
SUTTON
RIVERDALE
WHITINSVILLE
MENDON
HOPEDALE
Whitins Pond
Manchaug Pond
Wallis Reservoir
DOUGLAS
WHEELOCKVILLE
UXBRIDGE
BELLINGHAM
MILLVILLE
BLACKSTONE
WRENTHAM
MASS.
CONN.
R.I.
Wallum Lake
FORESTDALE
Slatersville Reservoir
MOHEGAN
NORTH SMITHFIELD
WOONSOCKET
PLAINVILLE
Diamond Hill Reservoir
NORTH ATTLEBOROUGH
MANVILLE
ALBION
CUMBERLAND
LINCOLN
ASHTON
PASCOAG
BURRILLVILLE
Pascoag Reservoir
CHEPACHET
GLOCESTER
Smith & S Reservoir
ATTLEBOROUGH
VALLEY FALLS
LONSDALE
CENTRAL FALLS
PAWTUCKET
SEEKONK R.
PROVIDENCE
PROVIDENCE RIVER
SCALE IN MILES
LEGEND
INTERSTATE HIGHWAY
STREAM GAGING STATION (USGS)
SNOW SURVEY COURSE (C of E)
RIVER MILES
TOWN LINE BOUNDARIES
UXBRIDGE CITY OR TOWN
WATER RESOURCES DEVELOPMENT PRO
BLACKSTONE RIVER BAS
BASIN MAP
NEW ENGLAND DIVISION, WALTHAM,
JANUARY 1980



PLAN



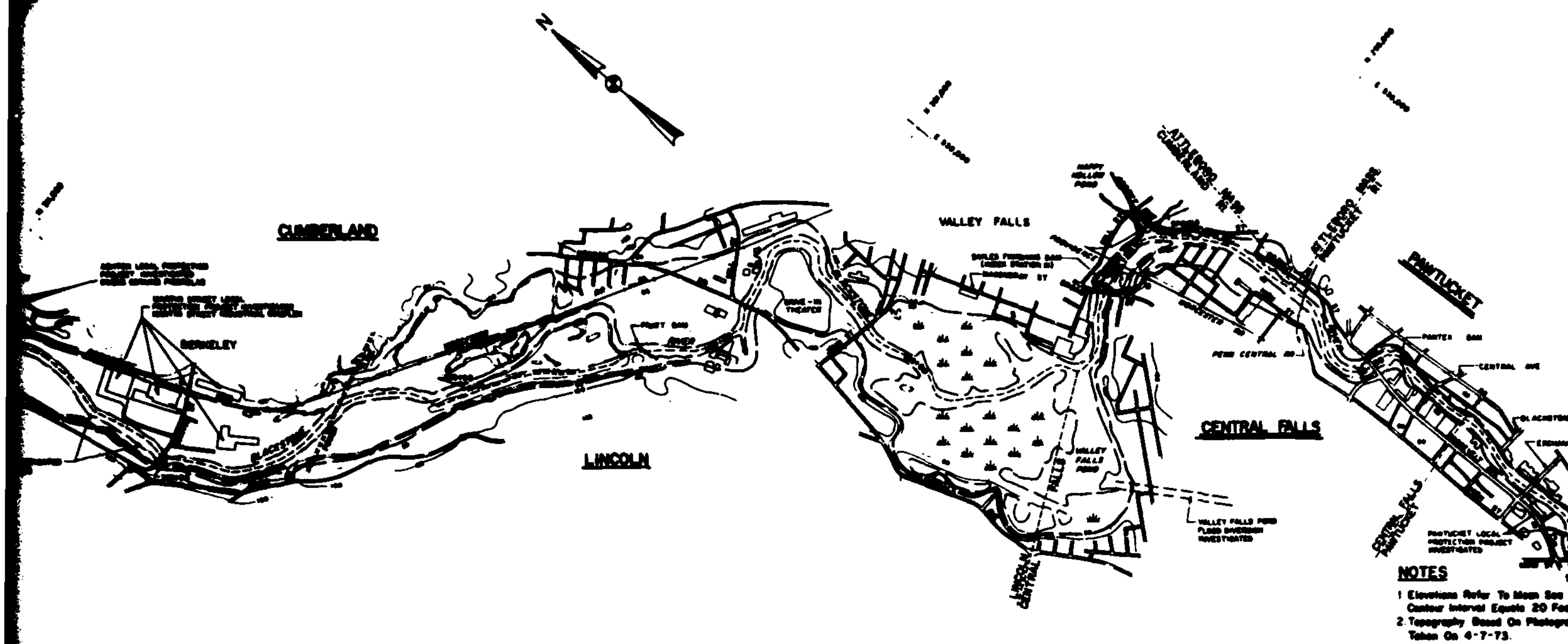
PROFILE

AD-A120 064 CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV F/G 13/2
PAWCATUCK RIVER AND NARRAGANSETT BAY DRAINAGE BASINS. WATER AND--ETC(U)
AUG 81

UNCLASSIFIED NL

5 OF 5

END
DATE FILMED
11-82
DTIC



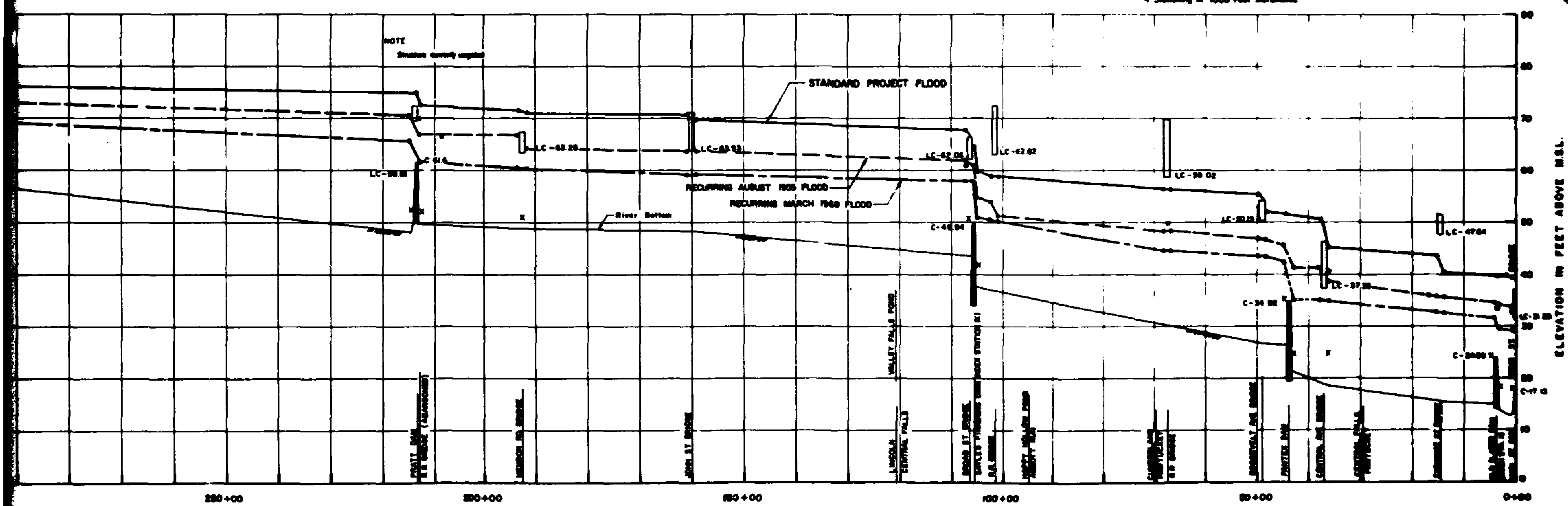
LEGEND

- Flood Plain (Recurring 1955 Storm)
- Normal Water Surface
- Observed High Water (1955)
- Calculated Recurring 1955 And 1968 High Water Marks
- Observed Normal Flow (Date 8-17-73 to 8-7-73)
- LC-0.00 Lowest Chord Elevation (MSL)
- C-0.00 Crest Elevation (MSL)
- Dam
- Bridge
- State Line
- City or Town Line
- PAWTUCKET City
- LINCOLN Town
- ASHTON Community or Hamlet
- Flood Control Project

NOTES

1. Elevations Refer To Mean Sea Level Datum of 1929. Contour Interval Equals 20 Feet, unless otherwise shown.
2. Topography Based On Photogrammetry (1"=1000') Taken On 4-7-73.
3. Horizontal Datum On Sheets 1 to 4 Is Based On The Plane Coordinate System For The State Of Rhode Island, and On Sheets 4 To 8 The Plane Coordinate System For The State Of Massachusetts. Grid Values For Both Systems Are Shown On Sheets 3 And 4 Where The Grid Zones Overlap.
4. Stationing In 1000 Feet Increments

PLAN



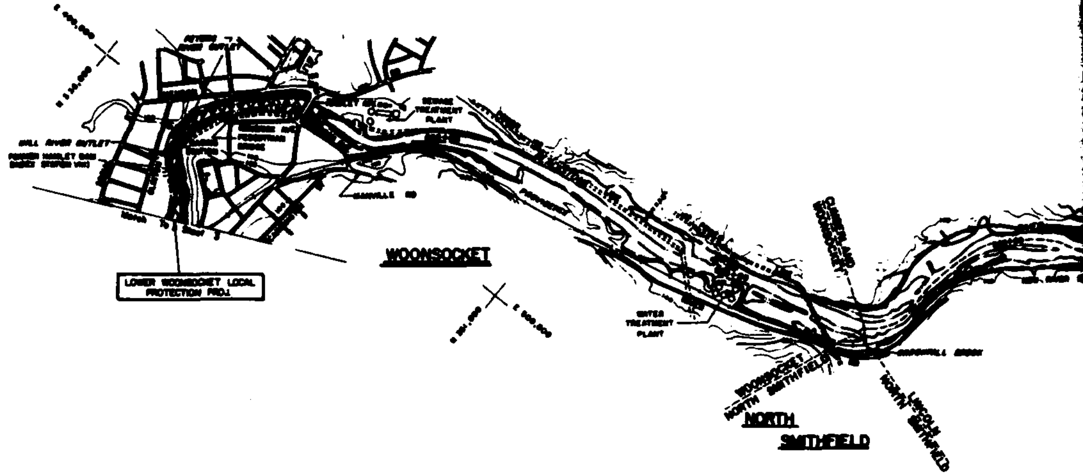
PROFILE

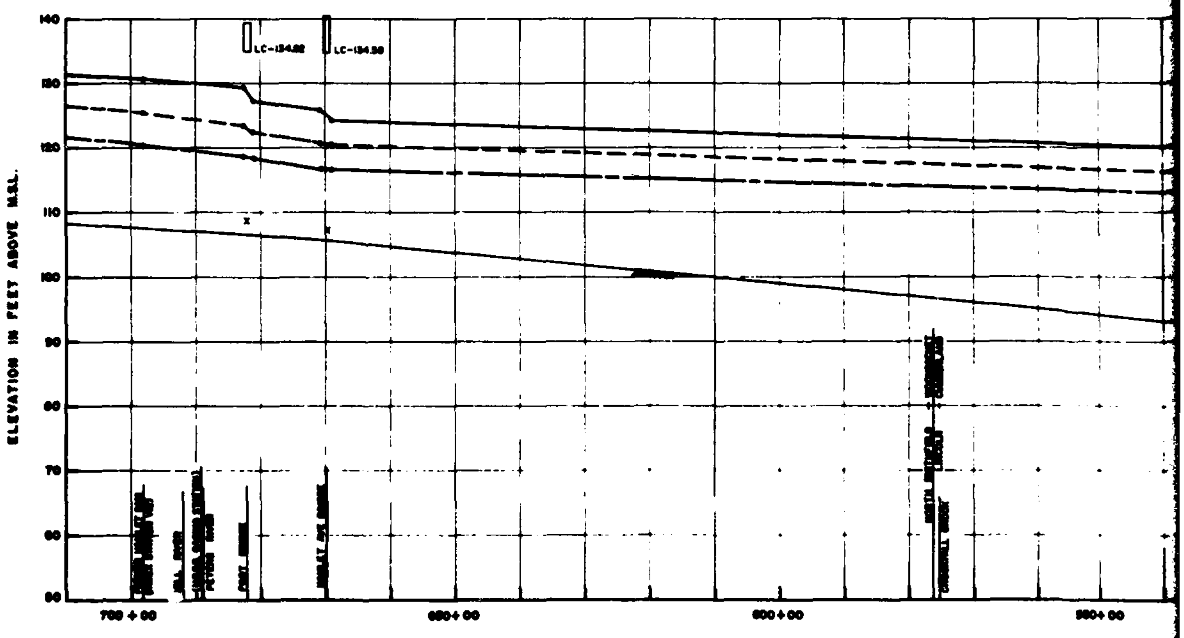
VERTICAL SCALE: 1" = 10'

CE MAGUIRE, INC. ARCHITECTS ENGINEERS PLANNERS	DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.

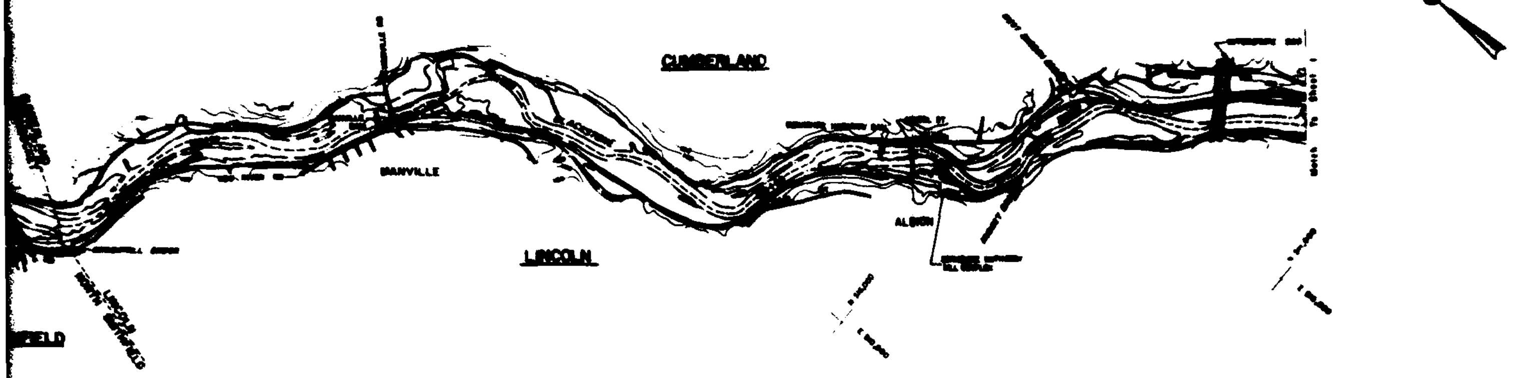
BLACKSTONE RIVER FLOOD CONTROL
BLACKSTONE RIVER
PLAN AND PROFILE
STATION 0+00 TO 280+00

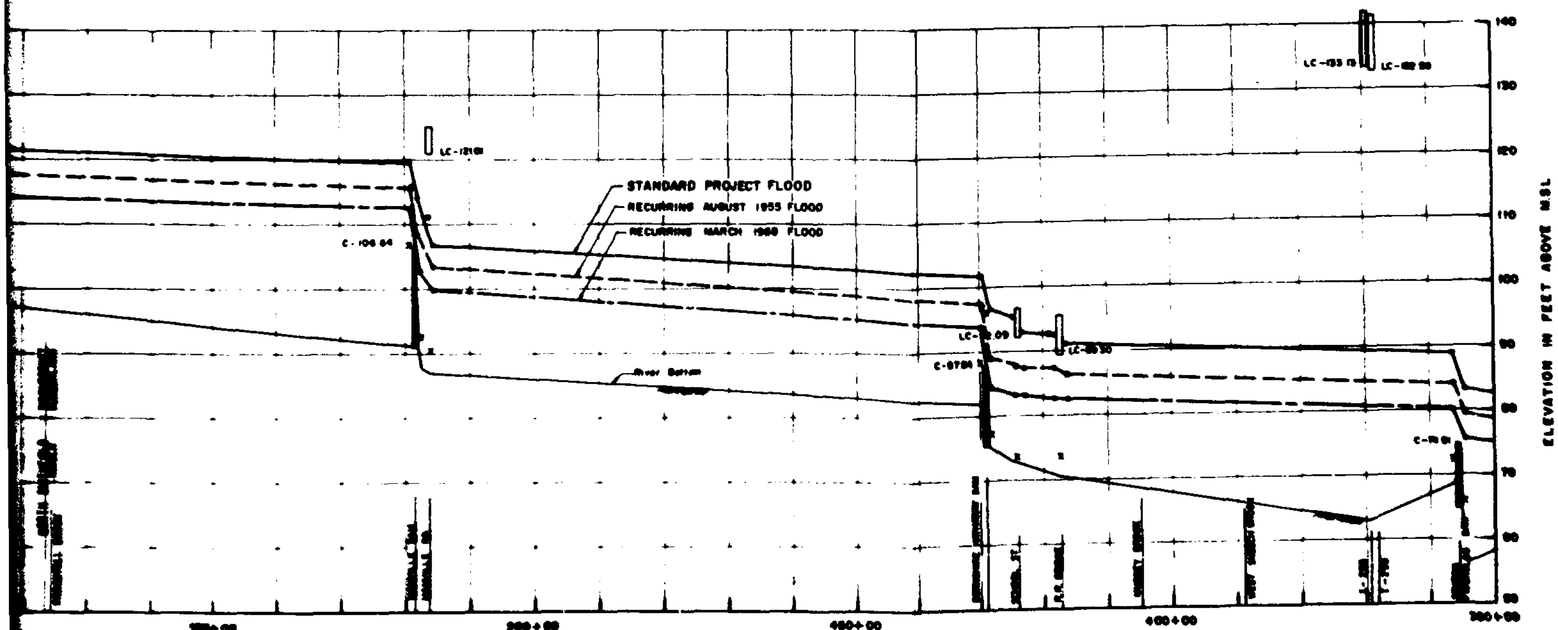
2





REVISION	DATE	DESCRIPTION	BY





BLACKSTONE RIVER FLOOD CONTROL

BLACKSTONE RIVER

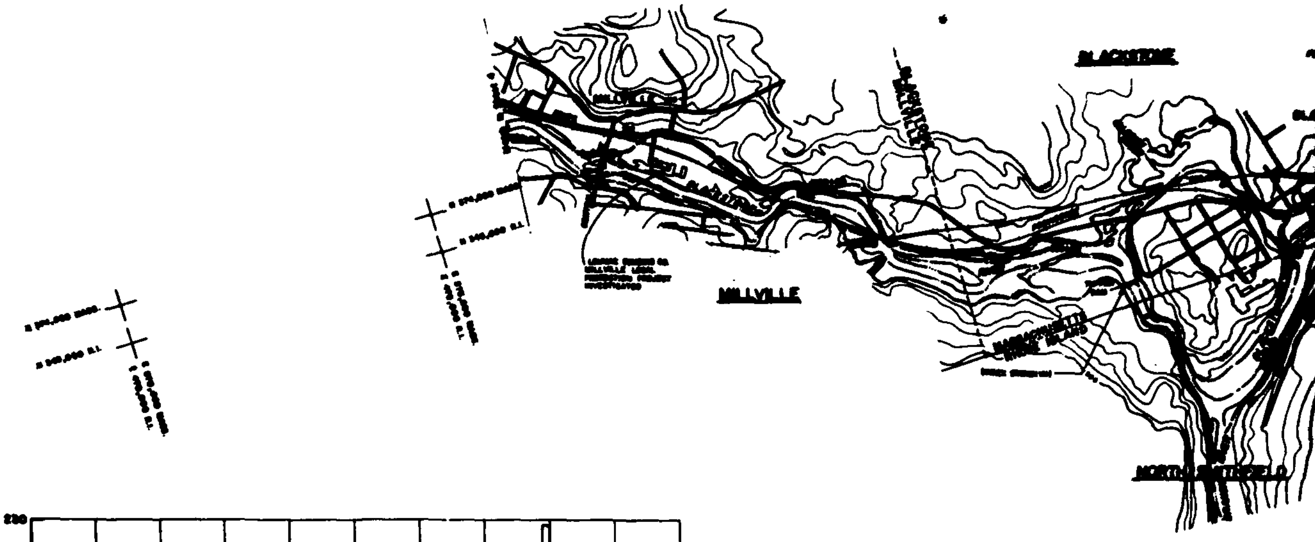
PLAN AND PROFILE

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

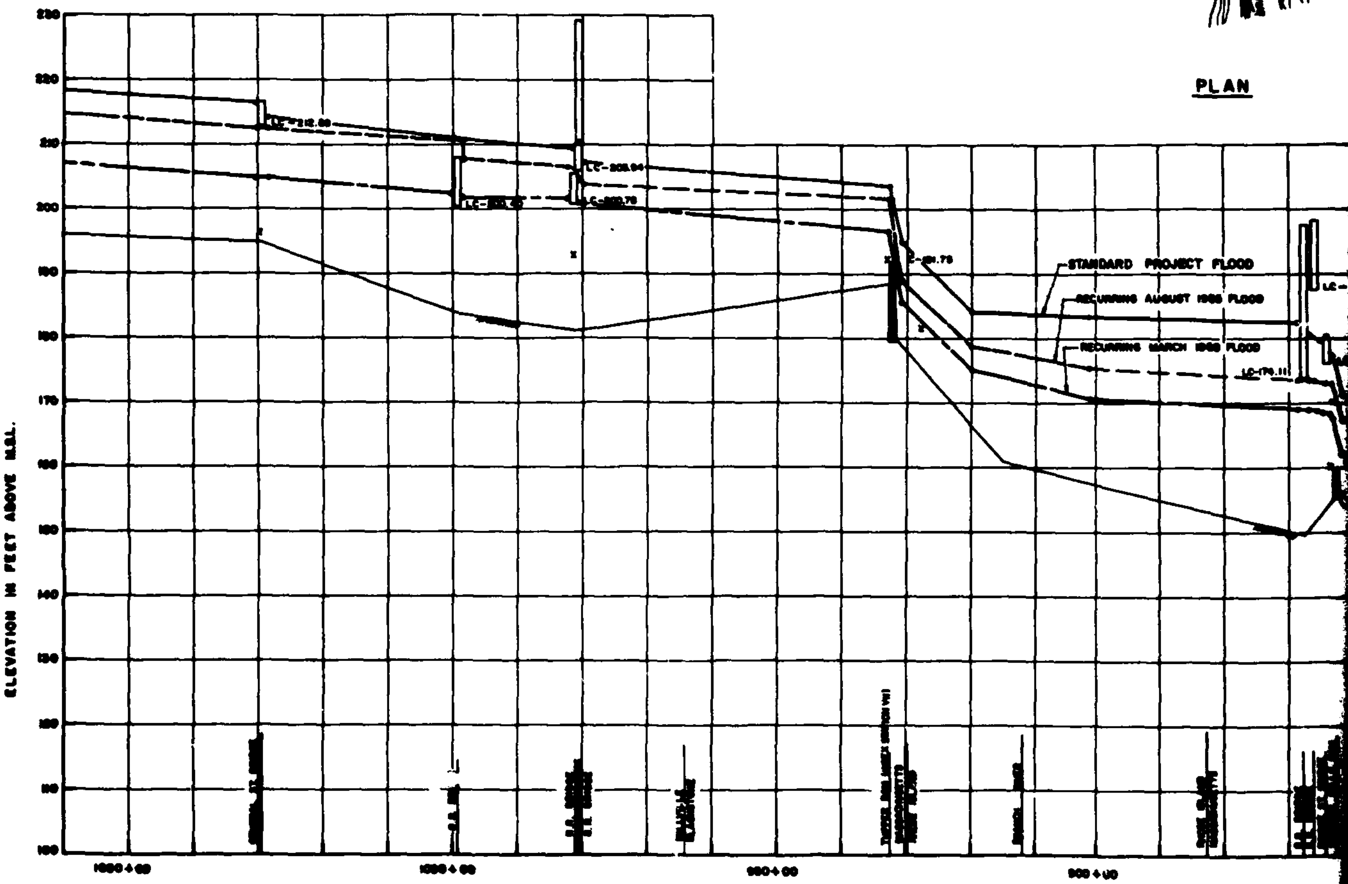
ARCHITECTS ENGINEERS PLANNERS

BLACKSTONE RIVER MASS & R.I.

PLATE 3



PLAN



PROFILE

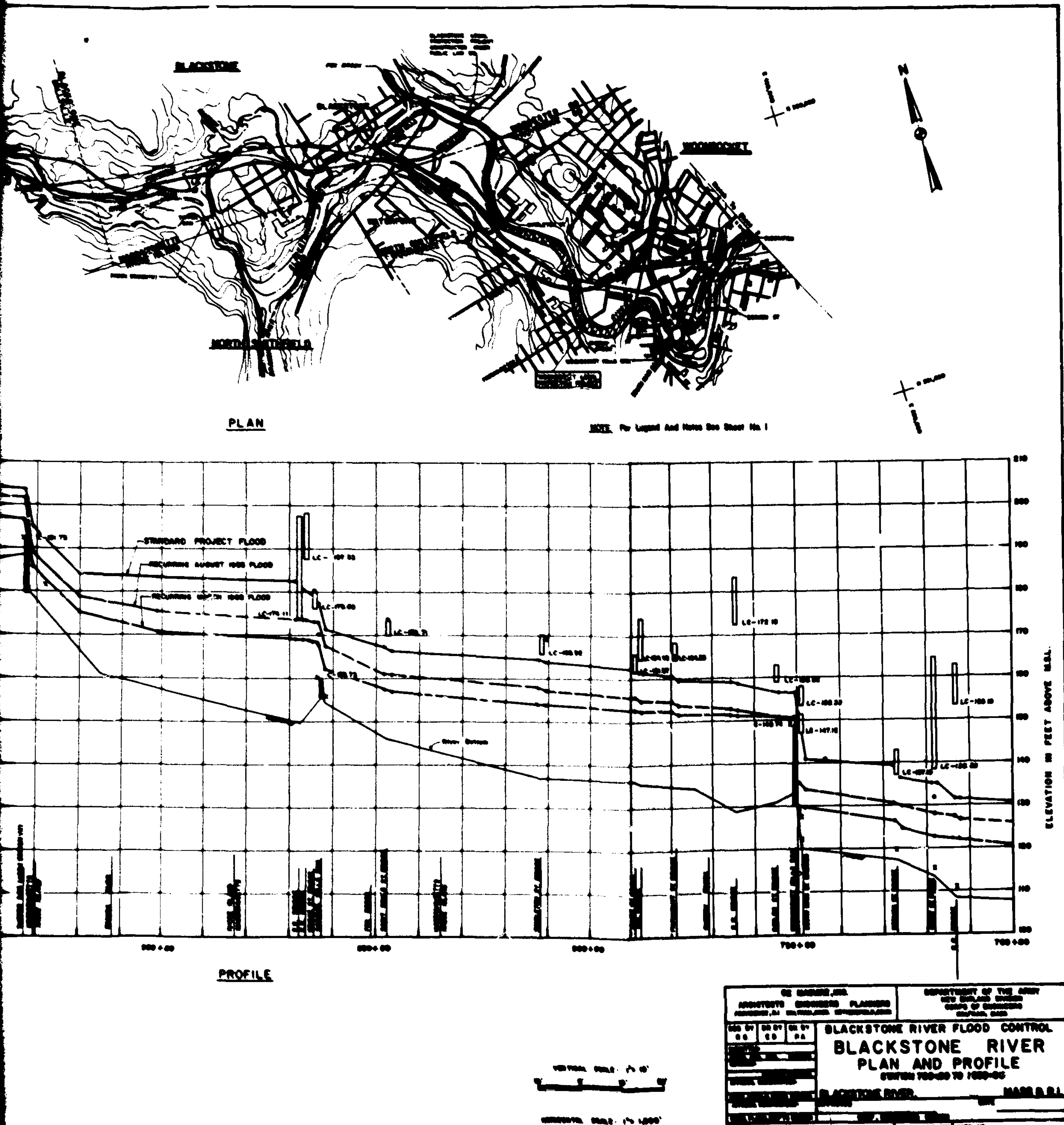
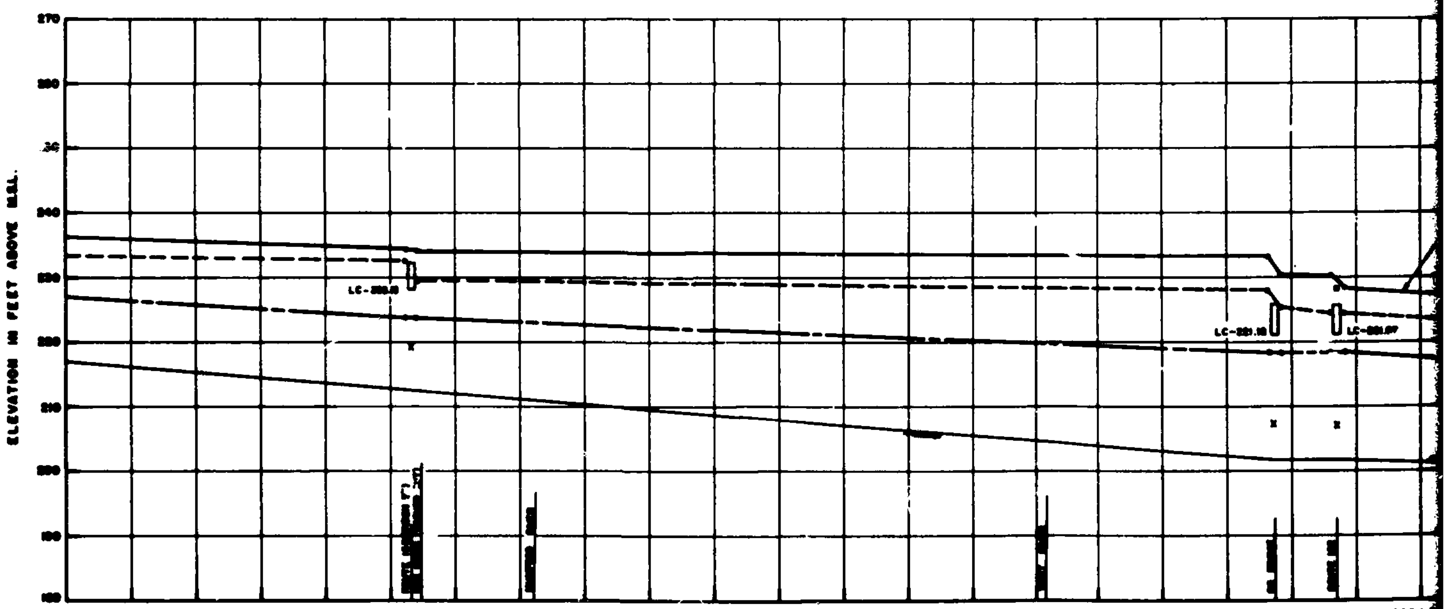
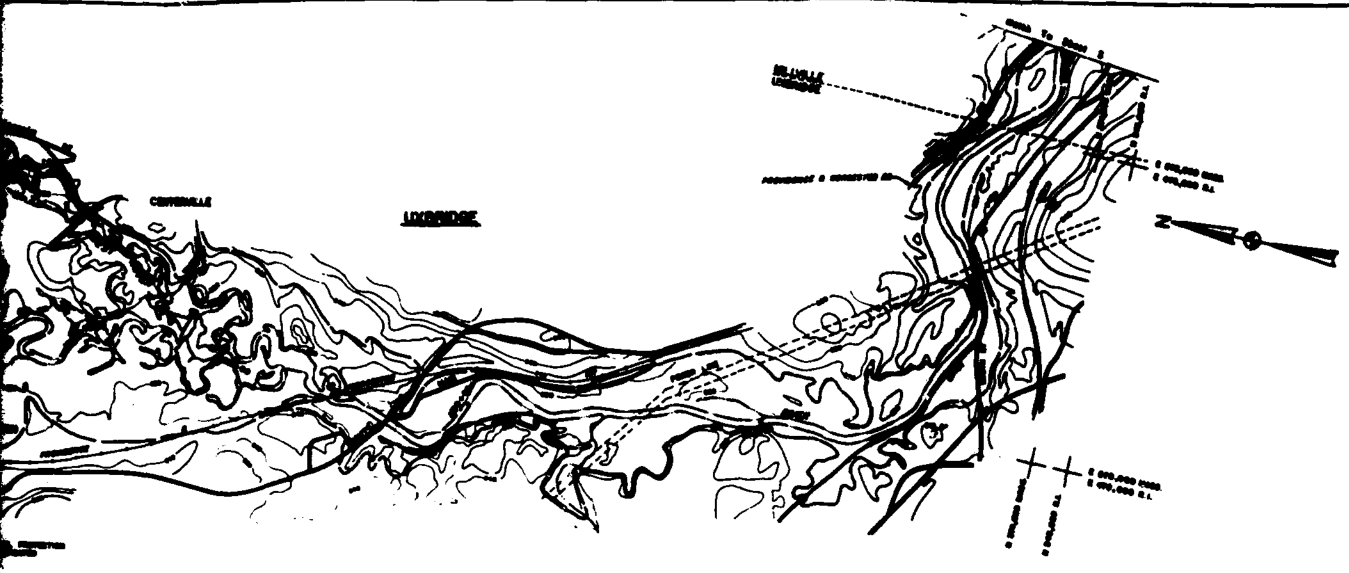

BLACKSTONE
WOONSOCKET
NORTH SMITHFIELD
PLAN
NOTE: For Legend And Notes See Sheet No. 1
STANDARD PROJECT FLOOD
ELEVATION IN FEET ABOVE M.S.L.
PROFILE
BLACKSTONE RIVER FLOOD CONTROL
BLACKSTONE RIVER
PLAN AND PROFILE

PLATE 4

PLAN

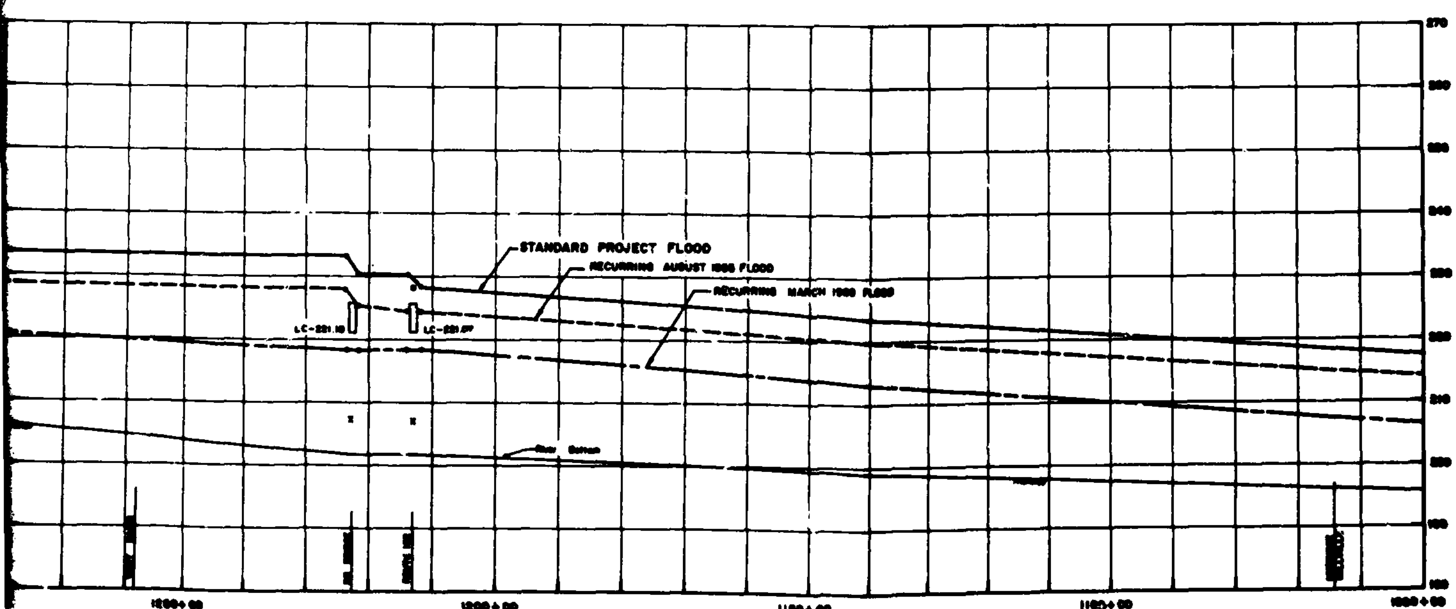


PROFILE



PLAN

NOTE: For Legend And Notes See Sheet No. 1



PROFILE

BLACKSTONE RIVER FLOOD CONTROL

BLACKSTONE RIVER

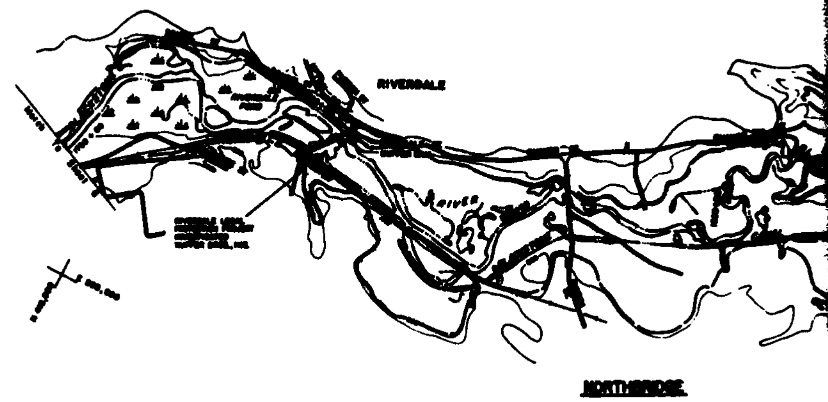
PLAN AND PROFILE

BLACKSTONE RIVER

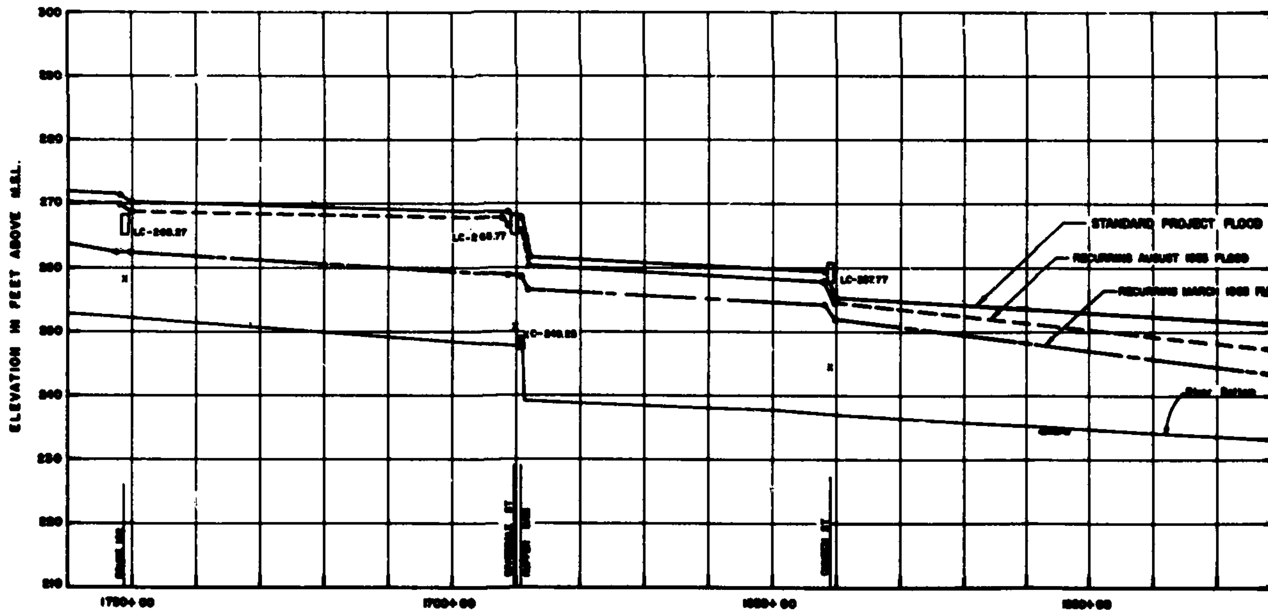
PLATE 5

2

1

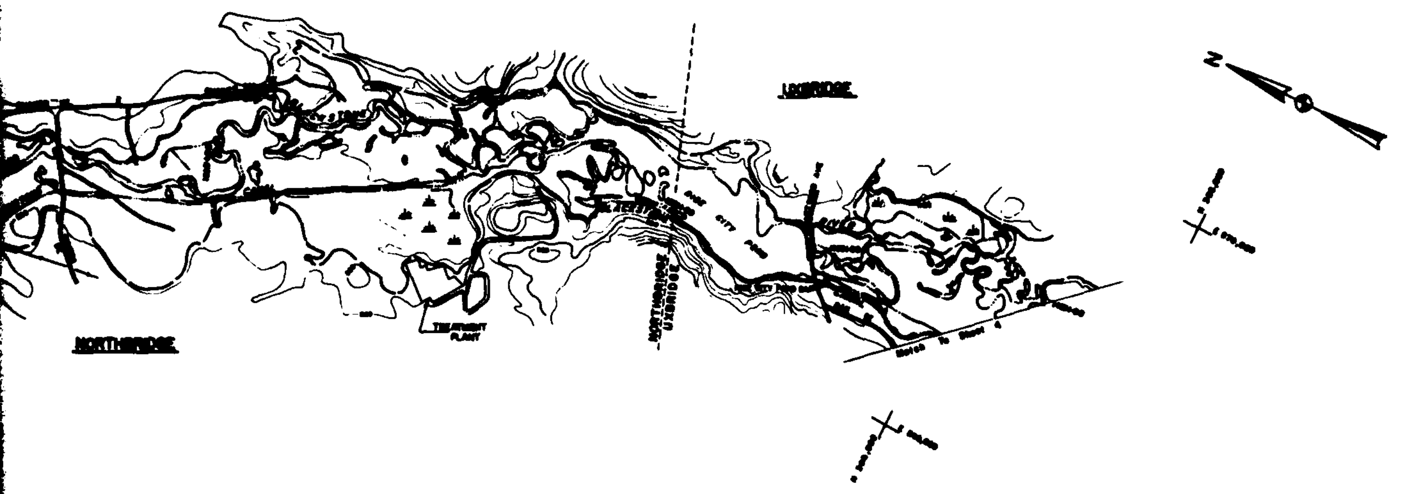


PLAN



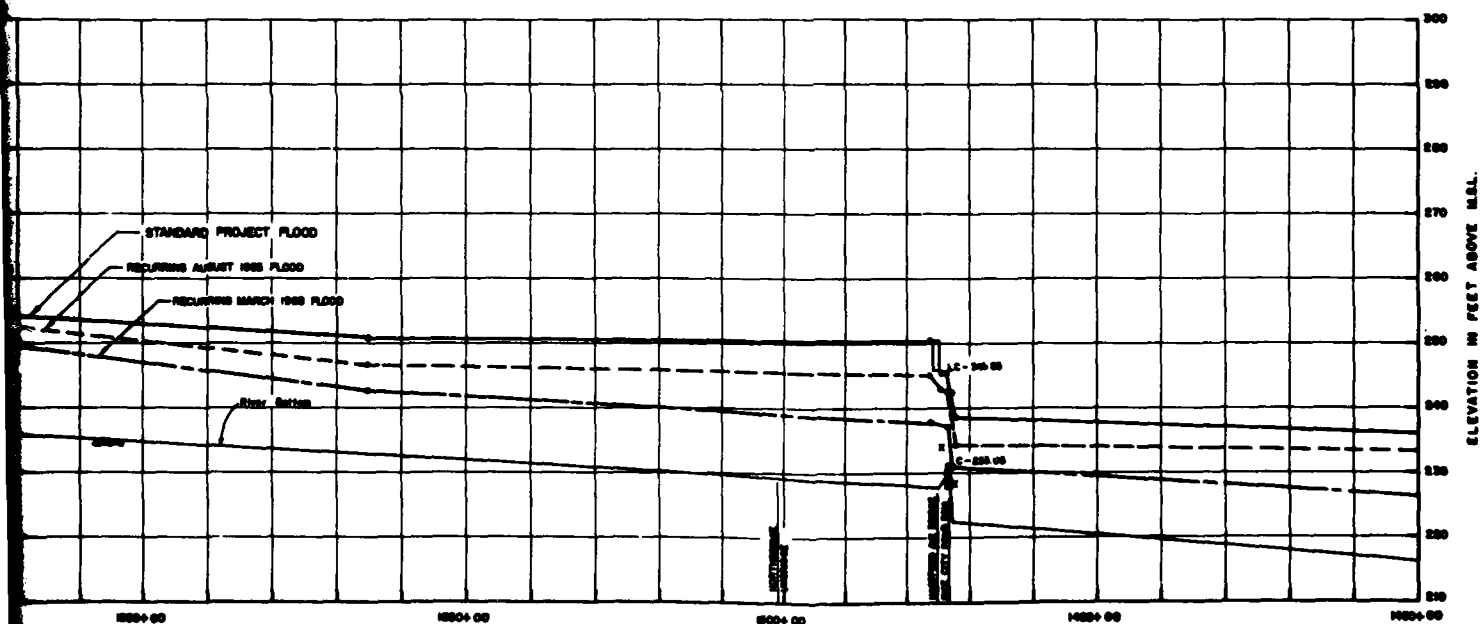
PROFILE

1

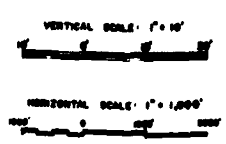


PLAN

NOTE: For Legend And Notes See Sheet No. I



PROFILE



DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

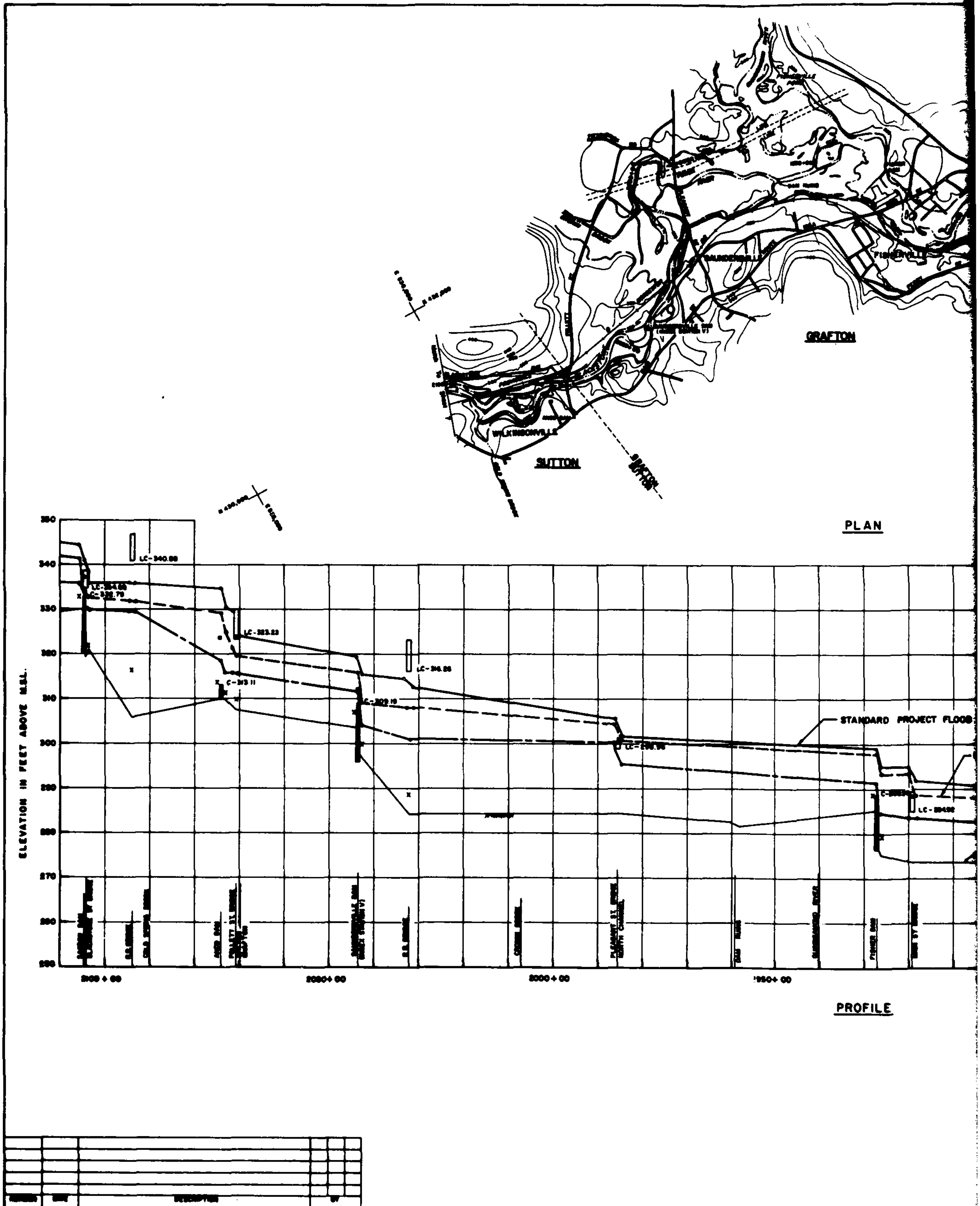
BLACKSTONE RIVER FLOOD CONTROL

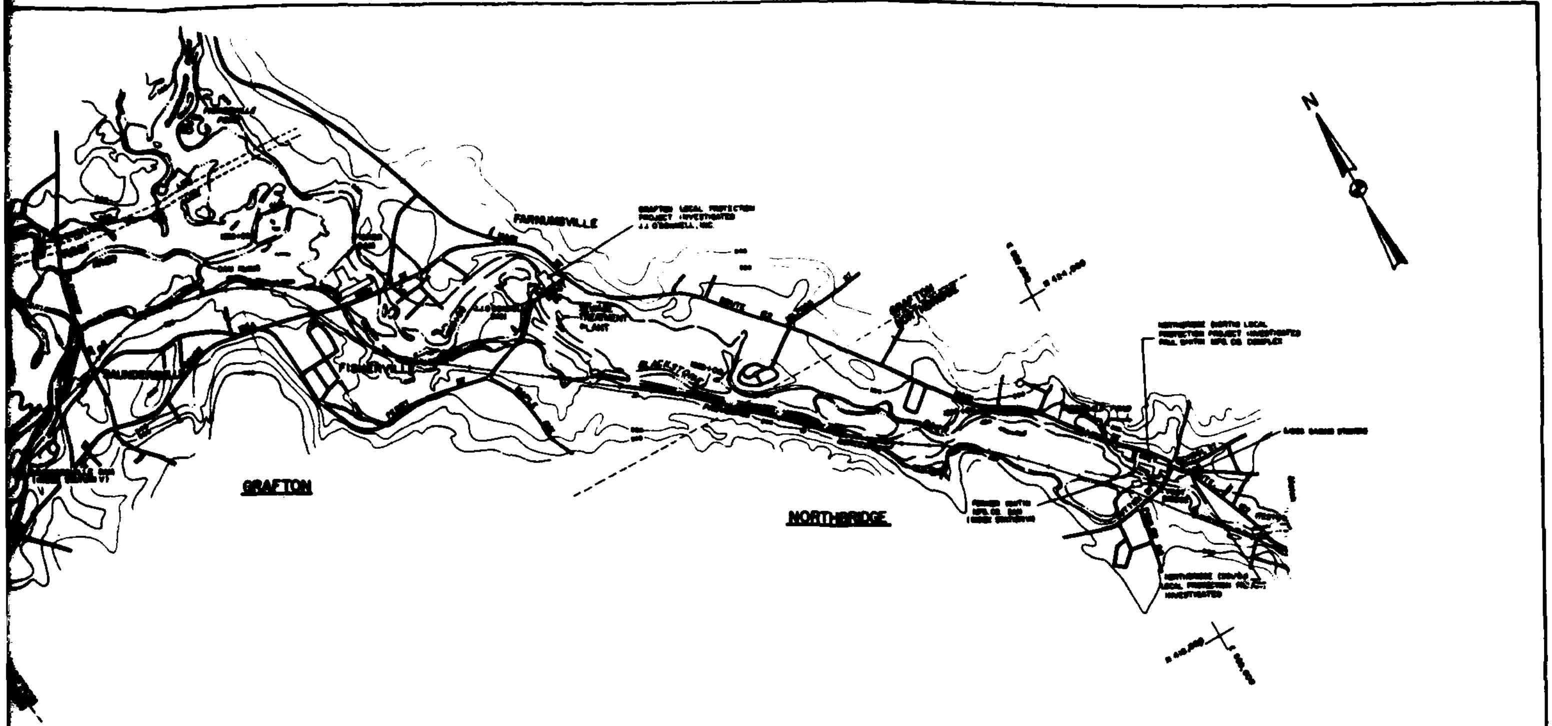
BLACKSTONE RIVER
PLAN AND PROFILE
STATION 1400+00 TO 1780+00

BLACKSTONE RIVER, MASS & R.I.

PLATE 6

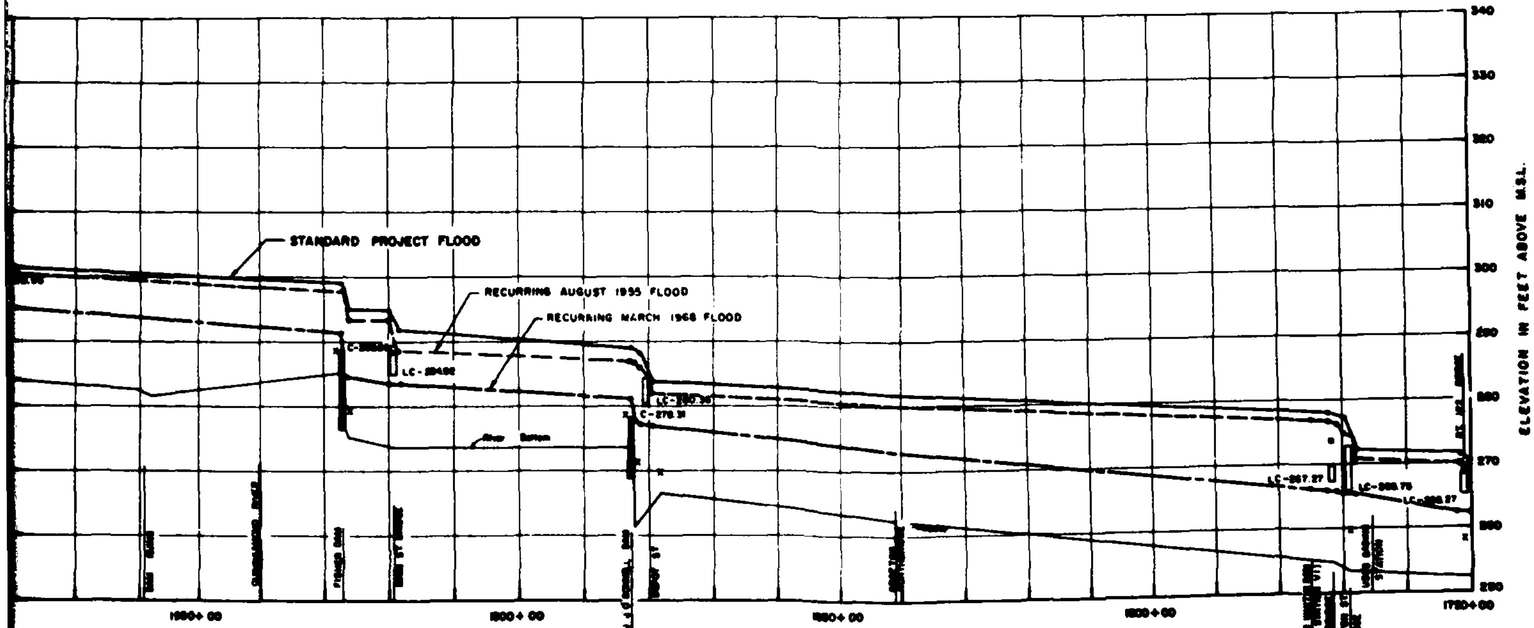
2


GRAFTON
SUTTON
WILKINSONVILLE
FISHERVILLE
SAUNDERSVILLE
PLAN
STANDARD PROJECT FLOOD
ELEVATION IN FEET ABOVE M.S.L.
350
340
330
320
310
300
290
280
270
260
250
2100+00
2050+00
2000+00
1950+00
PROFILE



PLAN

NOTE: For Legend And Notes See Sheet No. 1



PROFILE

VERTICAL SCALE 1" = 10'

HORIZONTAL SCALE 1" = 1,000'

CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

BLACKSTONE RIVER FLOOD CONTROL

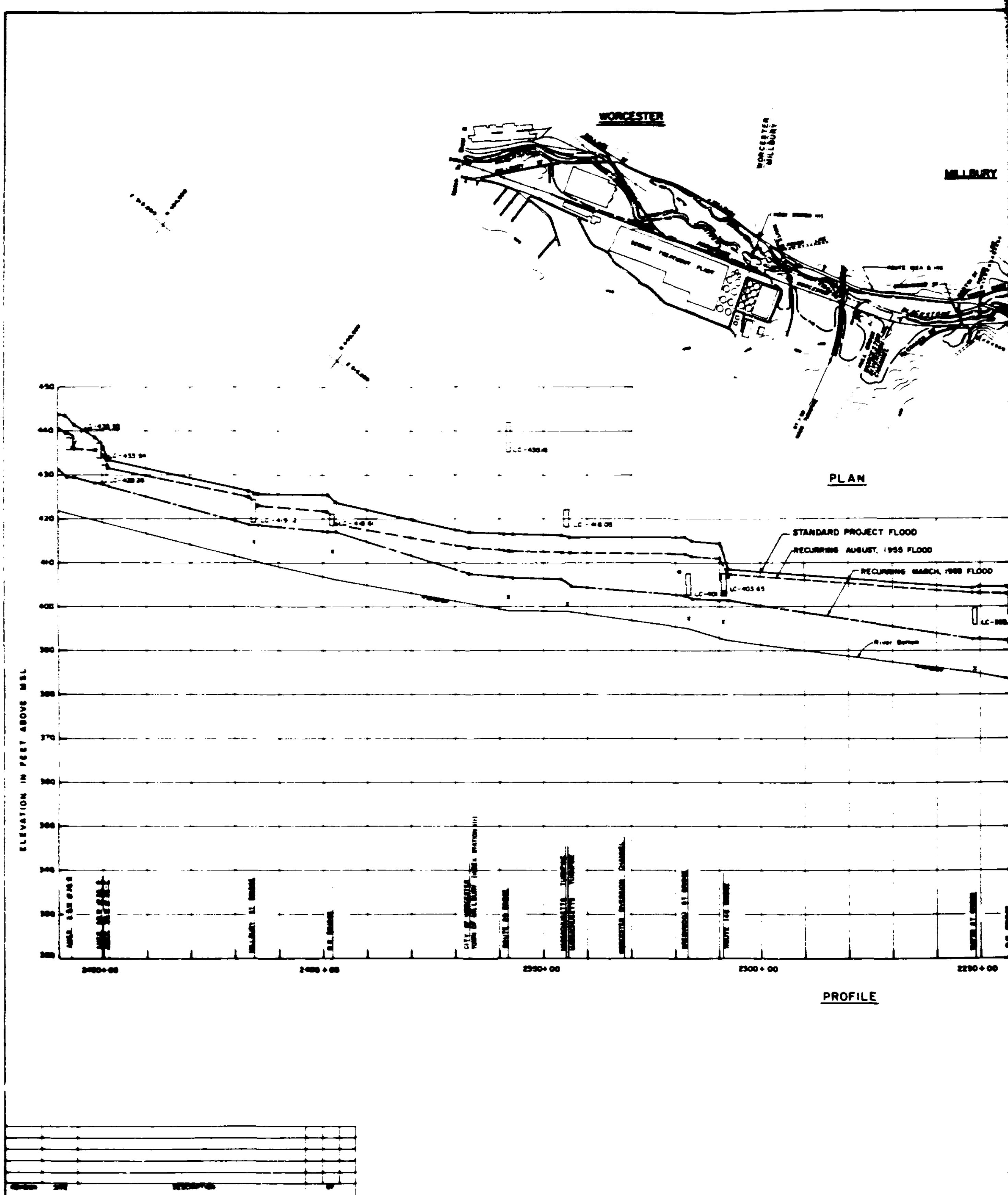
BLACKSTONE RIVER
PLAN AND PROFILE
STATION 1780+00 TO 2100+00

BLACKSTONE RIVER, MASS & R.I.

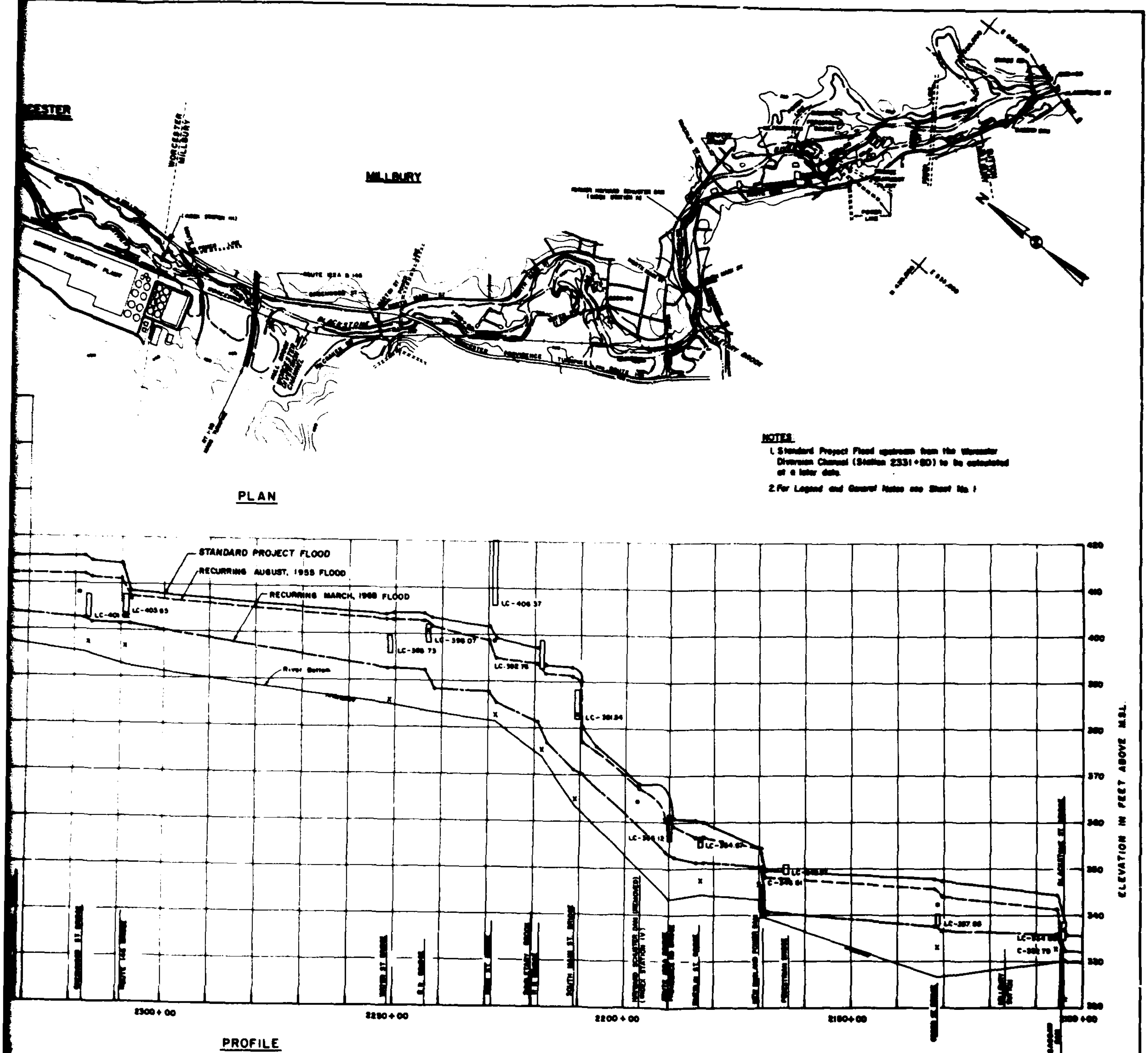
PLATE 7

2

1



WORCESTER
WORCESTER
MILLBURY
MILLBURY
PLAN
STANDARD PROJECT FLOOD
RECURRING AUGUST, 1955 FLOOD
RECURRING MARCH, 1968 FLOOD
River Bottom
ELEVATION IN FEET ABOVE MSL
2400+00
2300+00
PROFILE



CE MAGUIRE, INC. ARCHITECTS ENGINEERS PLANNERS	DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.

DSG. BY	DR. BY	CK. BY
R.G.	E.B.	P.A.

BLACKSTONE RIVER FLOOD CONTROL

BLACKSTONE RIVER
PLAN AND PROFILE

STATION 2100+00 TO 2330+00

BLACKSTONE RIVER, MASS & R.I.

VERTICAL SCALE 1" = 10'

10' 0 10' 20'

HORIZONTAL SCALE 1" = 1,000'

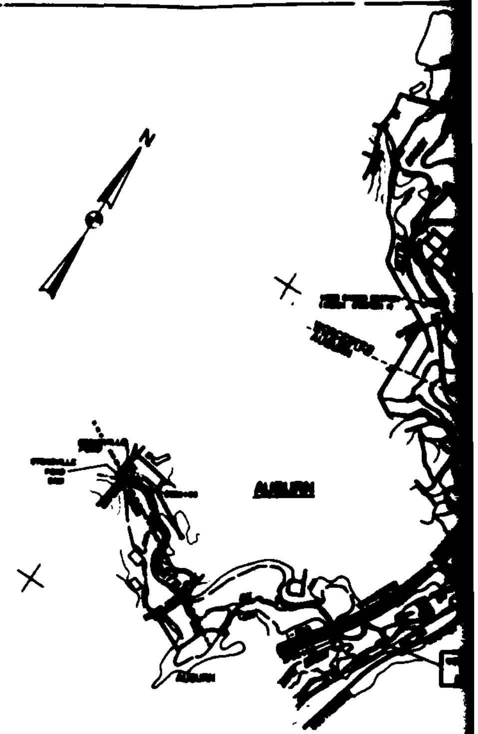
1000' 0 1000' 2000'

SHEET 7 of 8

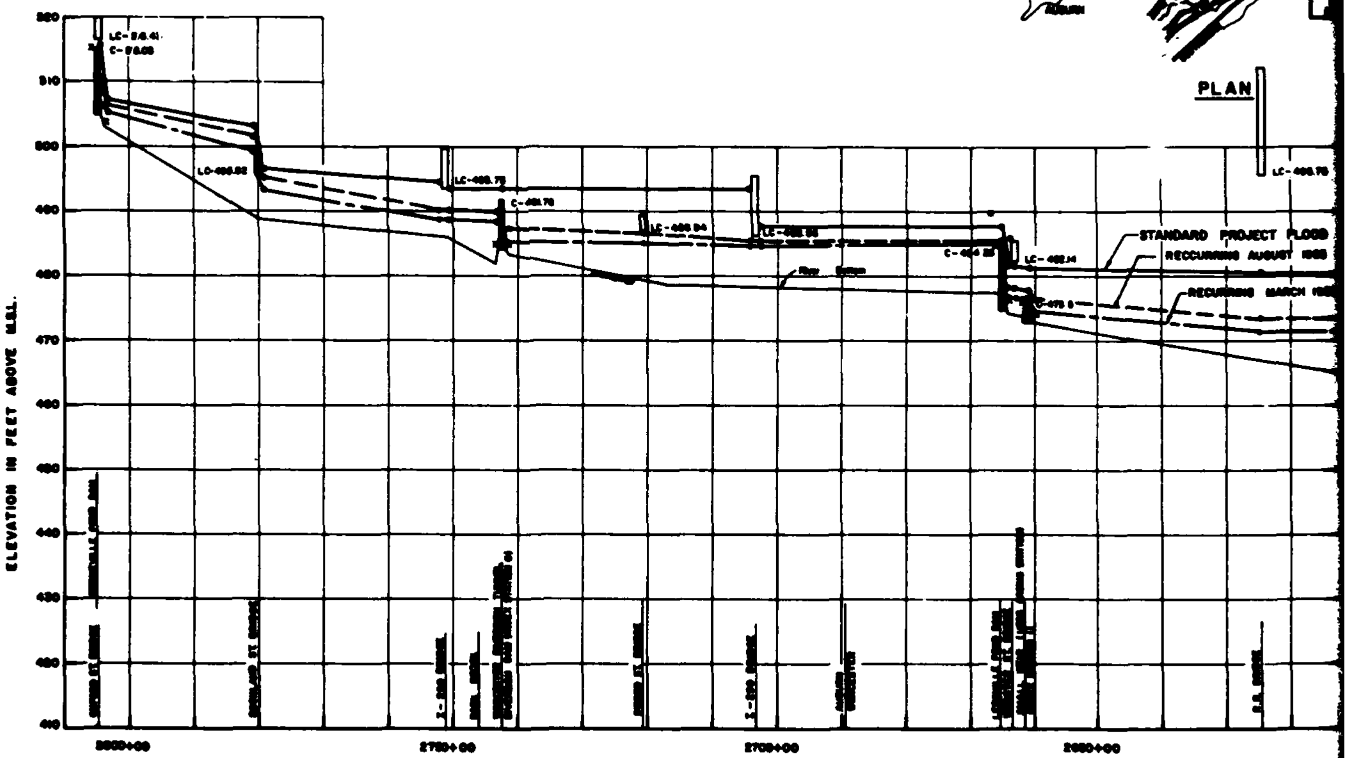
PLATE 8

1

2

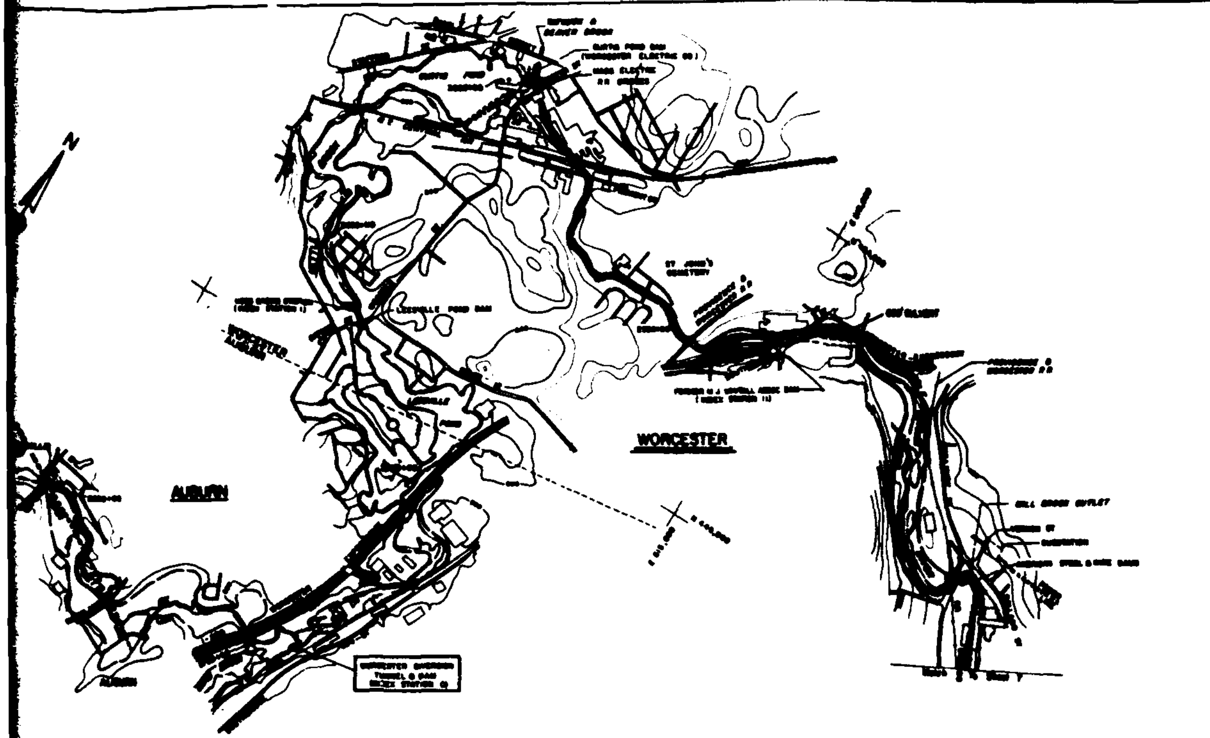


PLAN



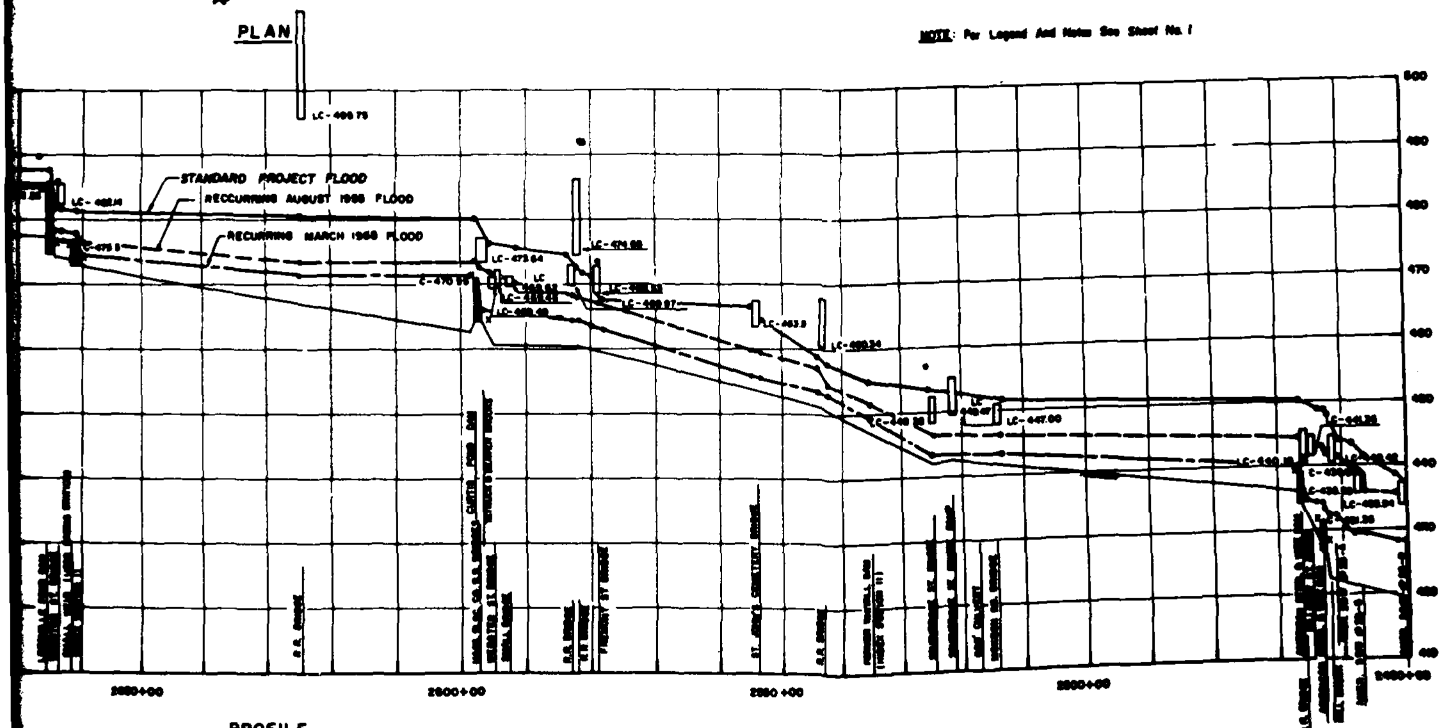
PROFILE

1



PLAN

NOTE: For Legend And Notes See Sheet No. 1



PROFILE

VERTICAL SCALE 1" = 10'

HORIZONTAL SCALE 1" = 1,000'

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

ARCHITECTS ENGINEERS PLANNERS

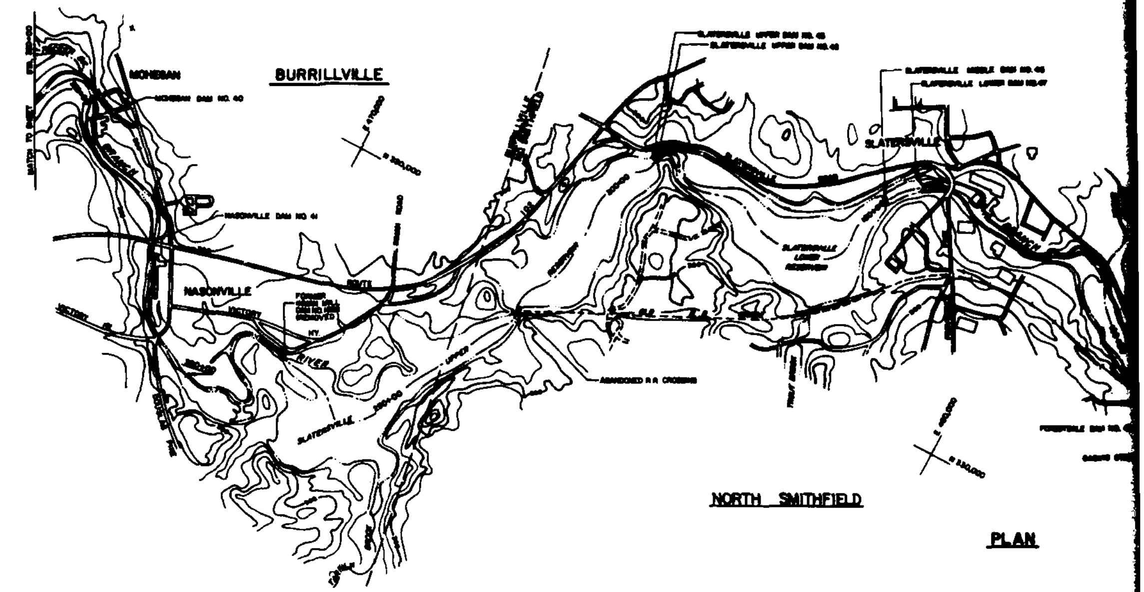
BLACKSTONE RIVER FLOOD CONTROL

BLACKSTONE RIVER
PLAN AND PROFILE

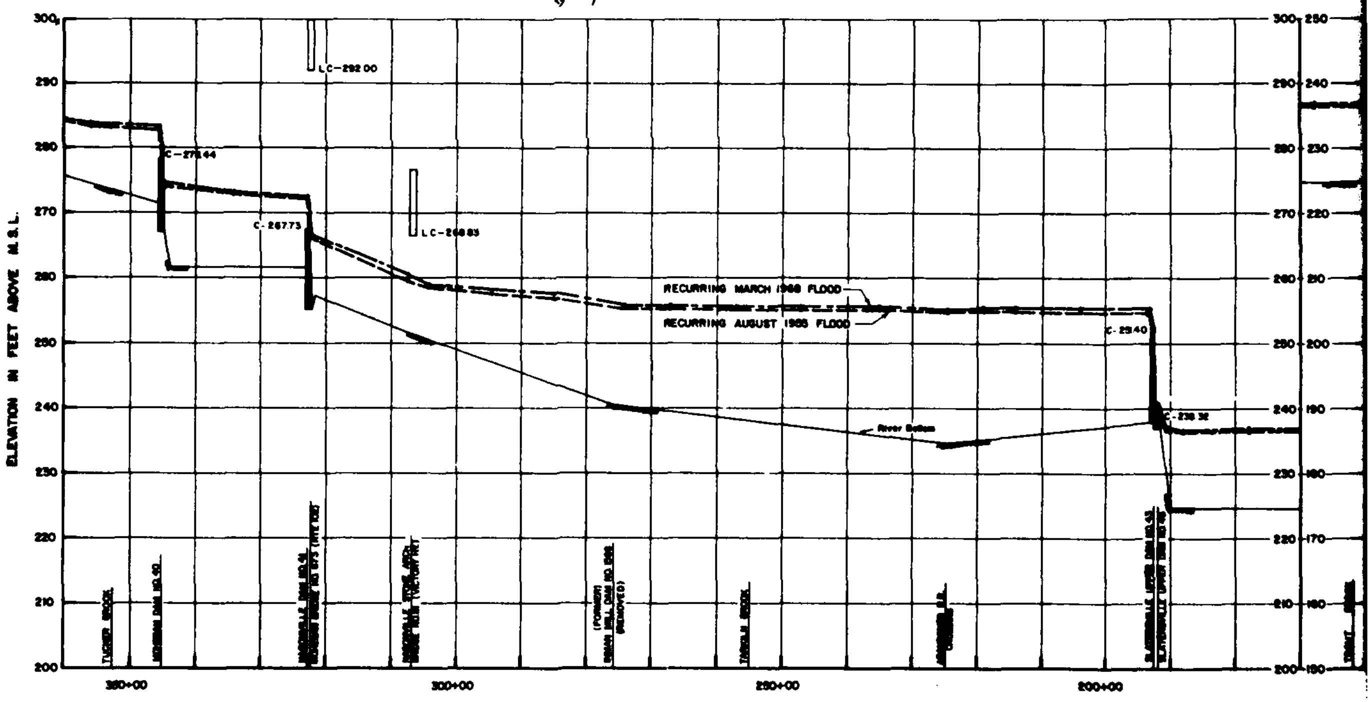
BLACKSTONE RIVER MASS & R.I.

PLATE 9

2



PLAN



PROFILE

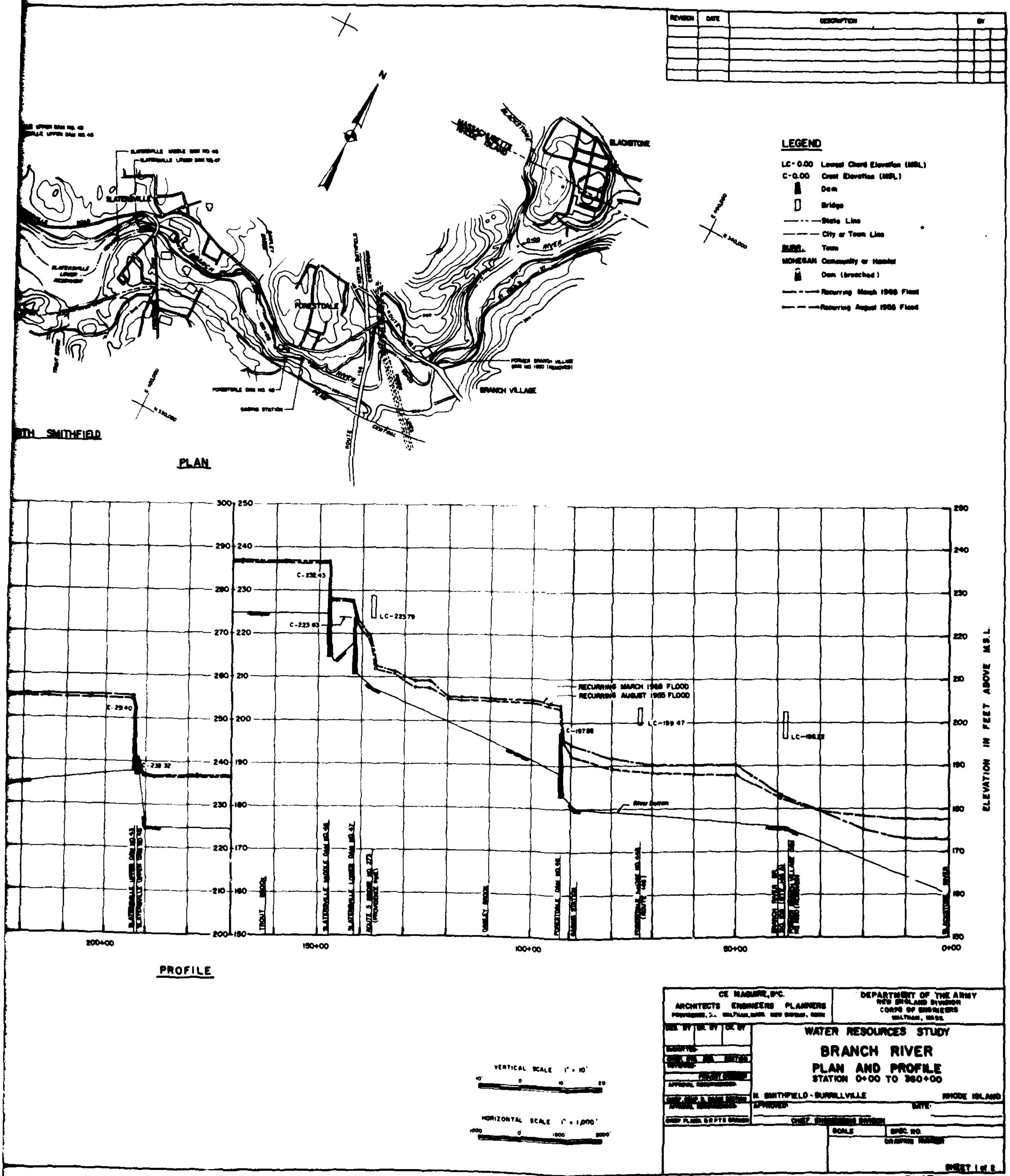
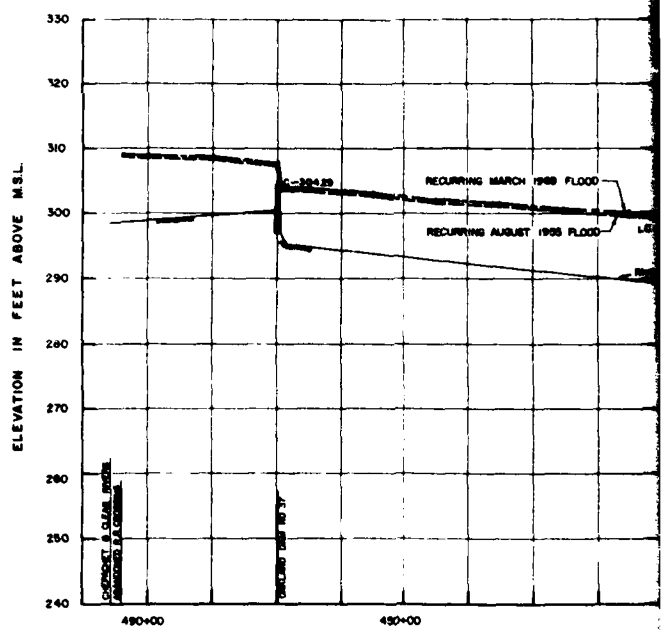
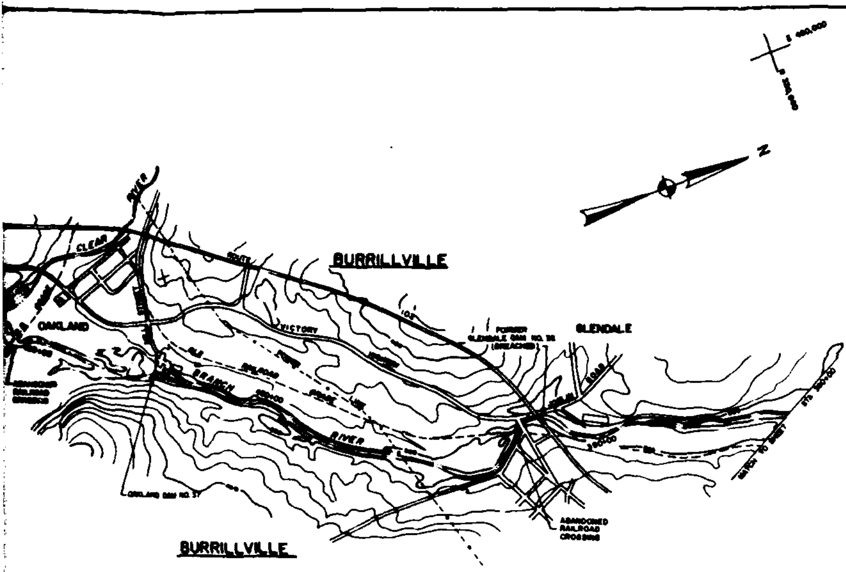

LEGEND
LC-0.00 Lowest Chord Elevation (MSL)
C-0.00 Crest Elevation (MSL)
Dam
Bridge
State Line
City or Town Line
Town
Community or Hamlet
Dam (breached)
Recurring March 1968 Flood
Recurring August 1955 Flood
BLACKSTONE
SLATERSVILLE
FORESTDALE
BRANCH VILLAGE
NORTH SMITHFIELD
PLAN
C-232.43
C-223.63
LC-223.79
C-229.40
C-238.32
RECURRING MARCH 1968 FLOOD
RECURRING AUGUST 1955 FLOOD
C-197.66
LC-199.47
LC-196.22
River Bottom
ELEVATION IN FEET ABOVE M.S.L.
200+00
150+00
100+00
50+00
0+00
PROFILE
VERTICAL SCALE 1" = 10'
HORIZONTAL SCALE 1" = 1,000'
CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES STUDY
BRANCH RIVER
PLAN AND PROFILE
STATION 0+00 TO 360+00
N. SMITHFIELD - BURRILLVILLE
RHODE ISLAND
SHEET 1 of 2

PLATE 10

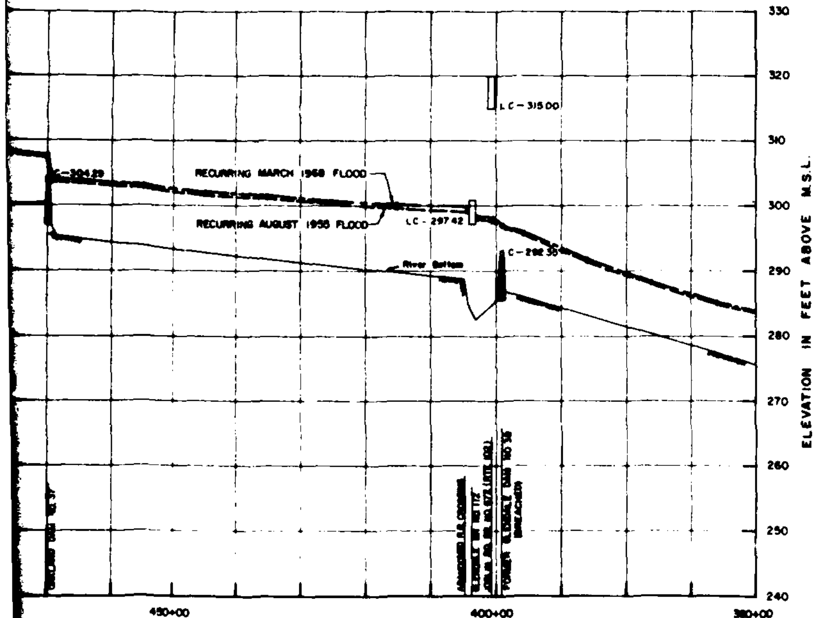
PLAN



PROFILE



PLAN



PROFILE

VERTICAL SCALE 1" = 10'

HORIZONTAL SCALE 1" = 1,000'

CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES STUDY

BRANCH RIVER

PLAN AND PROFILE

STATION 380+00 TO 500+00

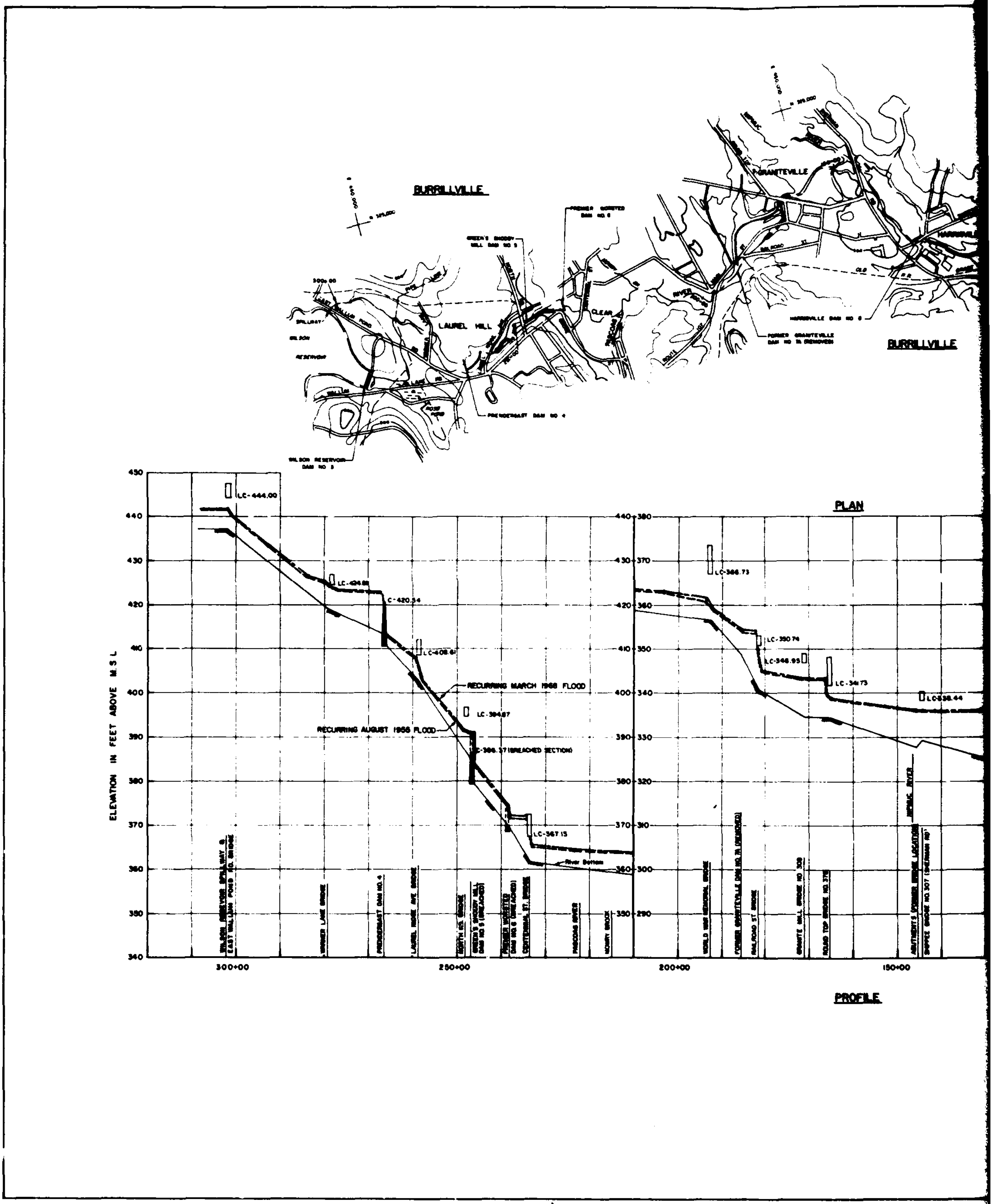
BURRILLVILLE, RHODE ISLAND

SHEET 2 of 2

PLATE 11

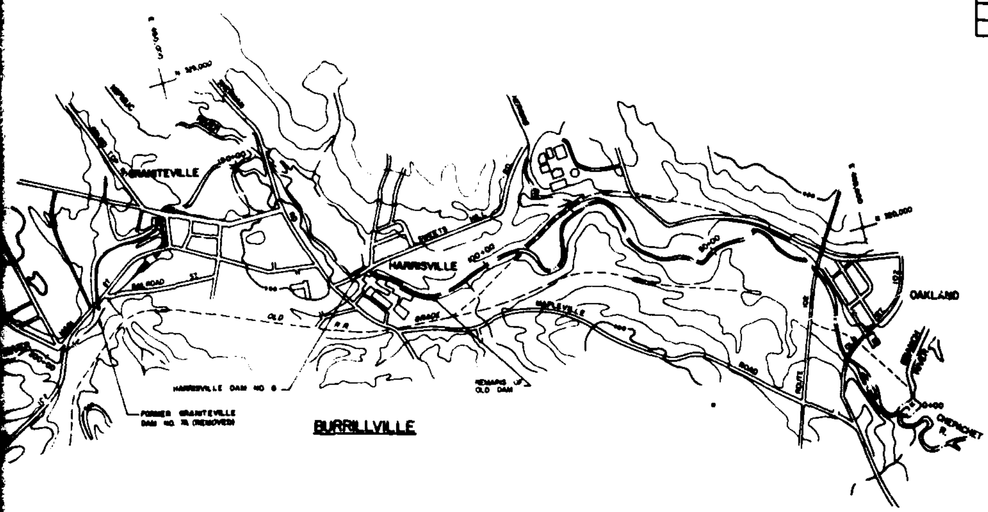
1

2

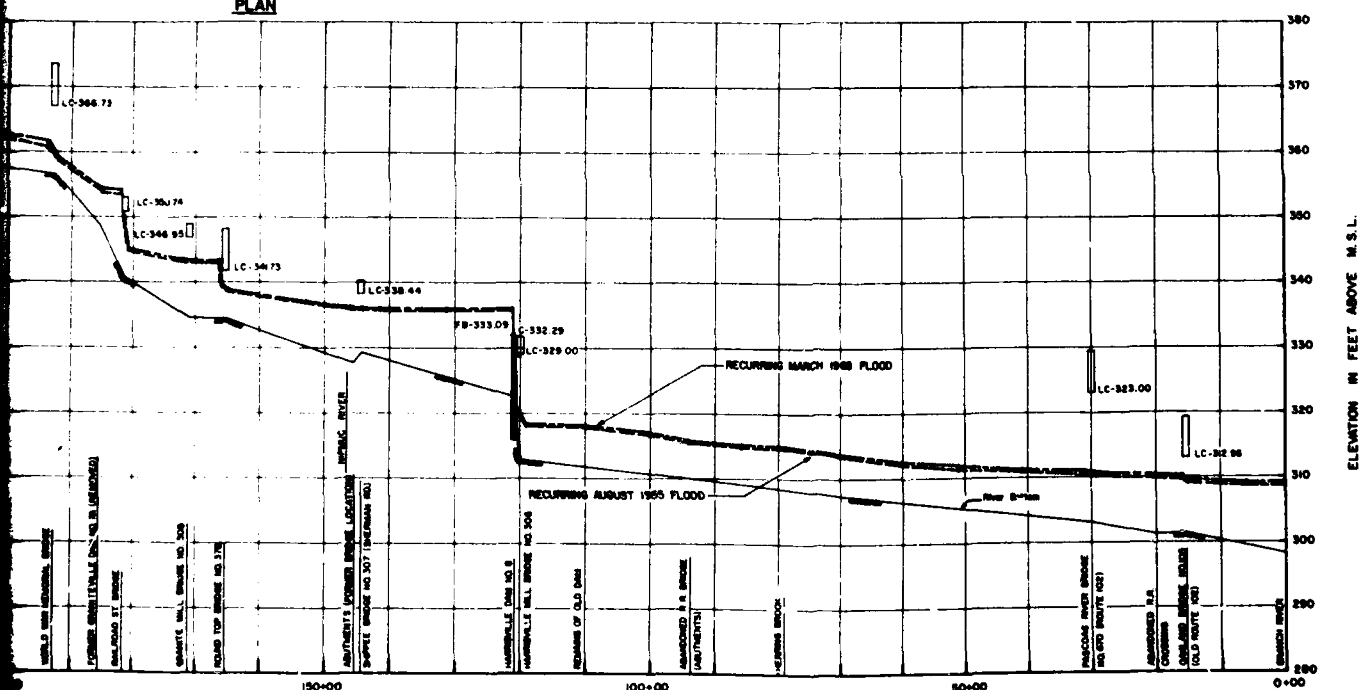


BURRILLVILLE
LAUREL HILL
CLEAR RIVER
GRANITEVILLE
PREMIER WORSTED DAM NO 6
GREEN'S SHODDY MILL DAM NO 5
PRENDERGAST DAM NO 4
WILSON RESERVOIR DAM NO 3
HARRISVILLE DAM NO 8
FORMER GRANITEVILLE DAM NO 7A (REMOVED)
PLAN
ELEVATION IN FEET ABOVE M.S.L
LC-444.00
LC-424.88
C-420.54
LC-408.61
LC-394.87
LC-386.37 (BREACHED SECTION)
LC-367.15
LC-366.73
LC-350.74
LC-346.95
LC-341.73
LC-338.44
RECURRING MARCH 1968 FLOOD
RECURRING AUGUST 1955 FLOOD
River Bottom
WILSON RESERVOIR SPILLWAY & EAST WALLUM POND RD. BRIDGE
WARNER LANE BRIDGE
PRENDERGAST DAM NO.4
LAUREL RIDGE AVE BRIDGE
NORTH RD. BRIDGE
GREEN'S SHODDY MILL DAM NO 5 (BREACHED)
PREMIER WORSTED DAM NO.6 (BREACHED)
CENTENNIAL ST. BRIDGE
PASCOAG RIVER
WORLD WAR MEMORIAL BRIDGE
FORMER GRANITEVILLE DAM NO 7A (REMOVED)
RAILROAD ST. BRIDGE
ROAD TOP BRIDGE NO 376
CHEPACHET RIVER
SHIPPEE BRIDGE NO.307 (SHERMAN RD)
300+00
250+00
200+00
150+00
PROFILE

REVISION	DATE	DESCRIPTION	BY



PLAN



PROFILE

VERTICAL SCALE 1" = 10'

10' 0' 10' 20'

HORIZONTAL SCALE 1" = 1,000'

1000' 0' 1000' 2000'

CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

WATER RESOURCES STUDY

PASCOAG — CLEAR RIVER

PLAN AND PROFILE
STATION 0+00 TO 312+00

BURRILLVILLE, RHODE ISLAND

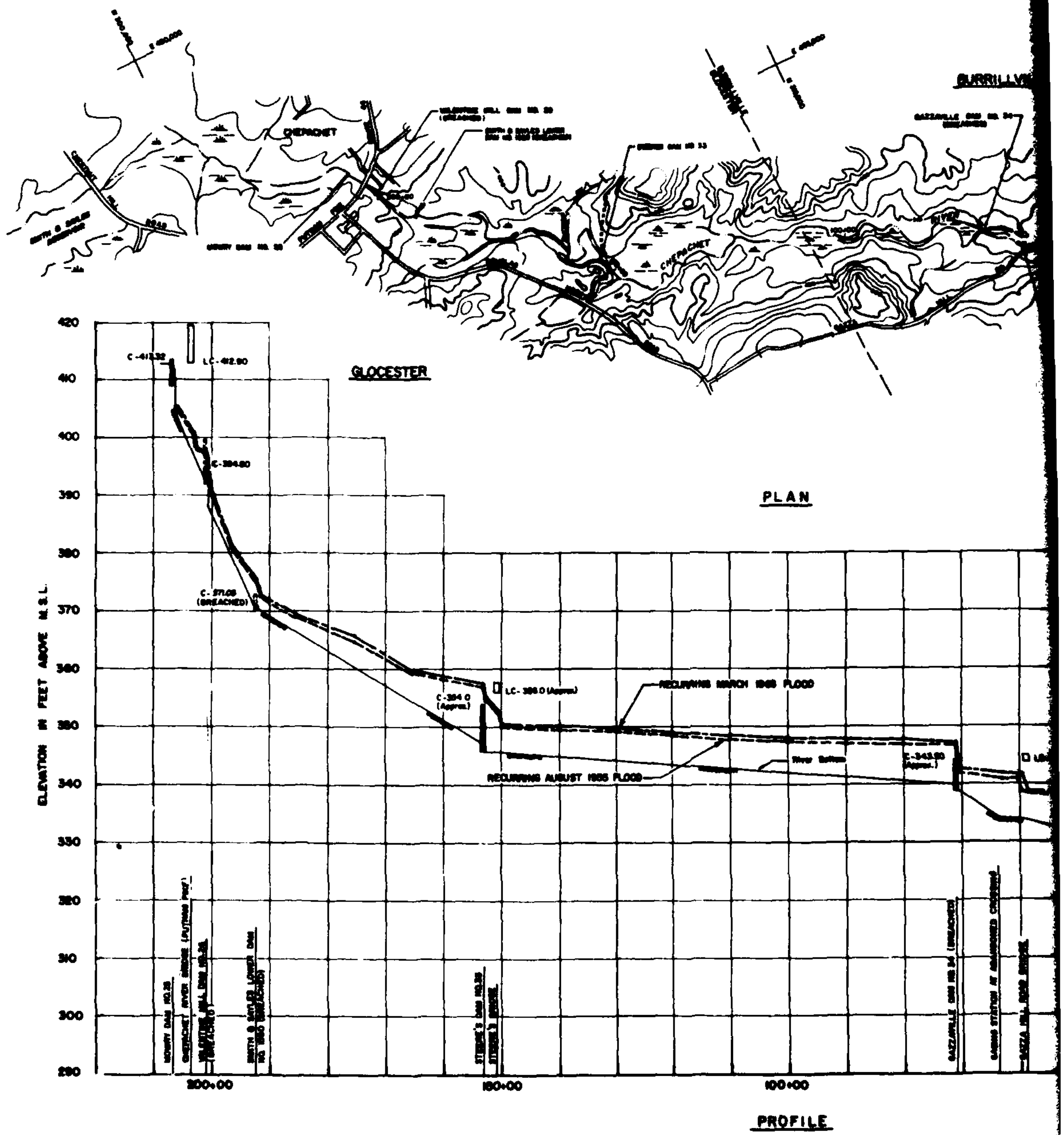
APPROVED: DATE:

SCALE: SPEC. NO.

DRAWING NUMBER

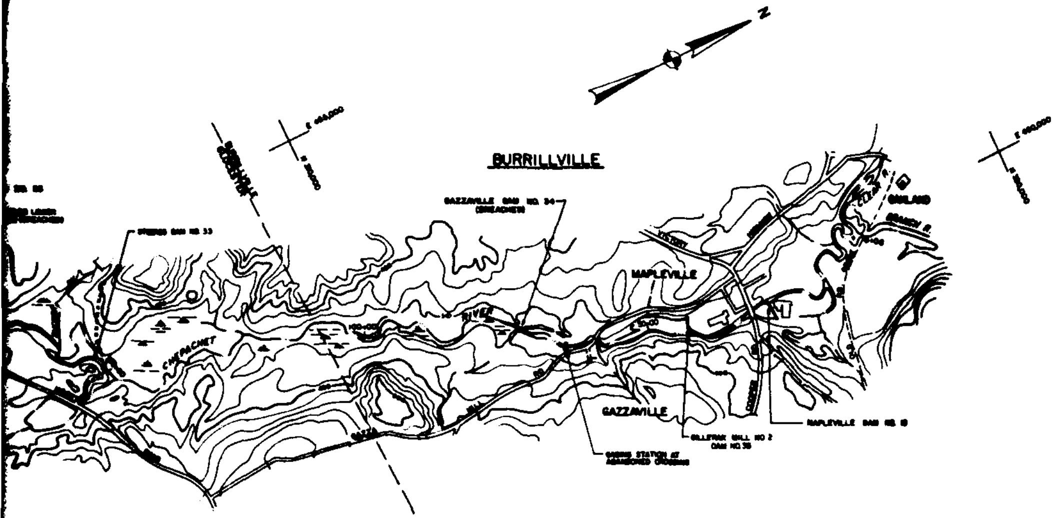
SHEET 1 of 1

PLATE 12

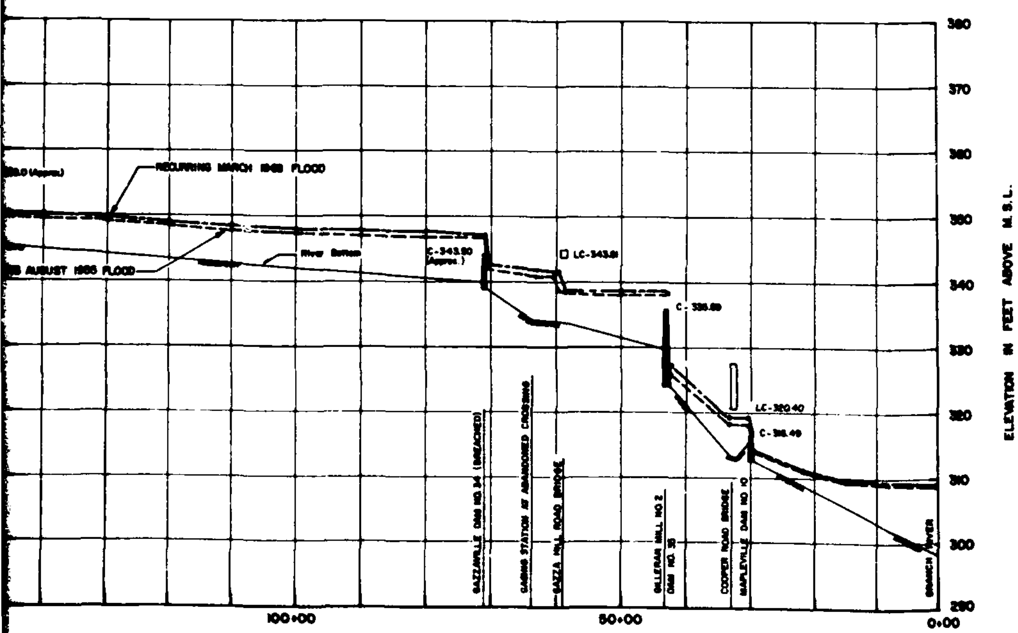


CHEPACHET
GLOCESTER
PLAN
PROFILE
ELEVATION IN FEET ABOVE M.S.L.
C-413.32
LC-412.80
C-394.80
C-371.05 (BREACHED)
C-354.0 (Approx.)
LC-356.0 (Approx.)
C-343.50 (Approx.)
RECURRING MARCH 1968 FLOOD
RECURRING AUGUST 1955 FLOOD
River Bottom
420
410
400
390
380
370
360
350
340
330
320
310
300
290
200+00
150+00
100+00

REVISION	DATE	DESCRIPTION	BY



PLAN



PROFILE

VERTICAL SCALE 1" = 10'

HORIZONTAL SCALE 1" = 1,000'

CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS
PROVIDENCE, R.I. WALTHAM, MASS NEW BRITAIN, CONN.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:

APPROVAL RECOMMENDED:

WATER RESOURCES STUDY

CHEPACHET RIVER

PLAN AND PROFILE

STATION 0+00 TO 206+70

BURRILLVILLE - GLOCESTER, RHODE ISLAND

APPROVED DATE

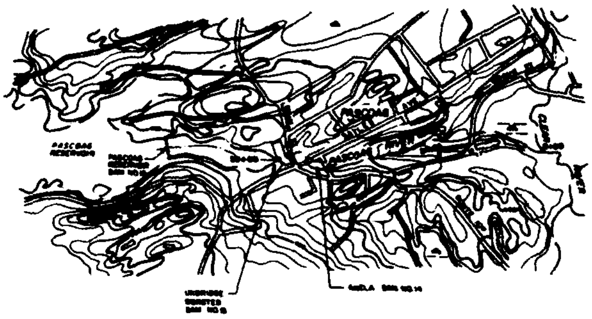
SCALE AS SHOWN SPEC. NO.

DRAWING NUMBER

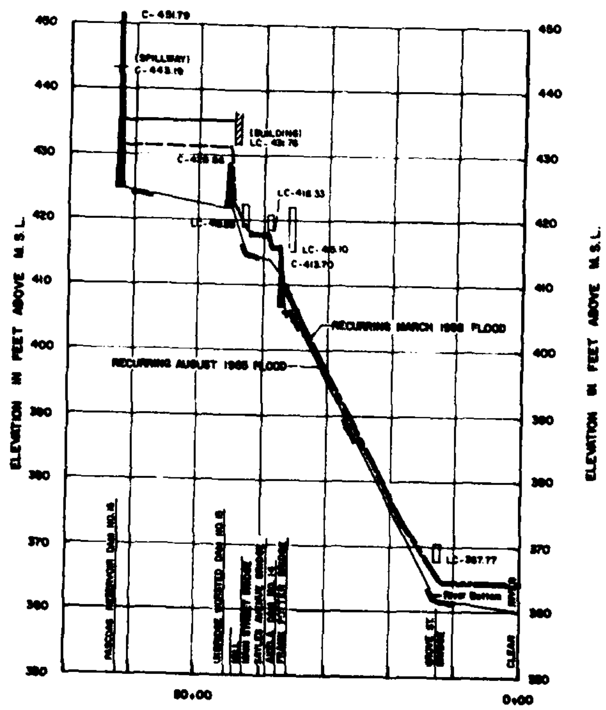
SHEET 1 of 1

PLATE 13

BURRILLVILLE



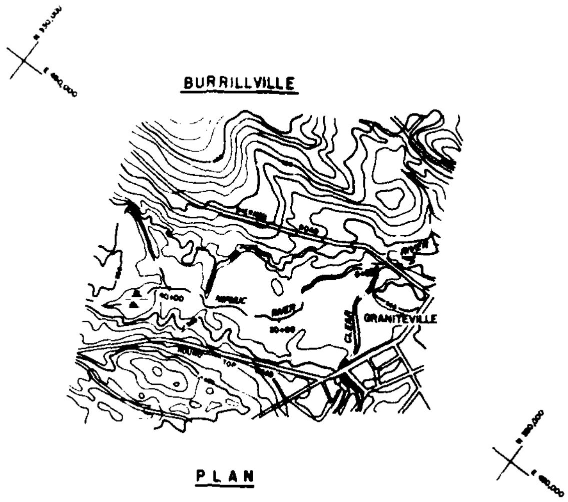
PLAN



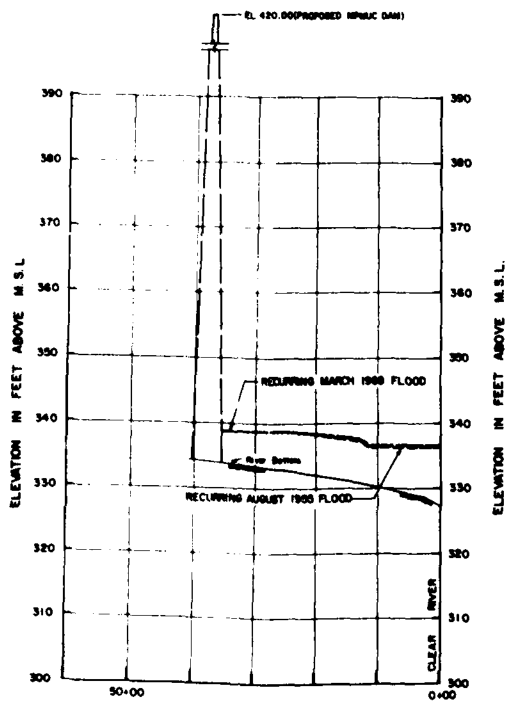
PROFILE

PASCOAG RIVER

REVISION	DATE	DESCRIPTION	BY

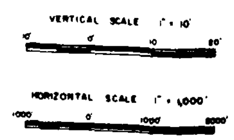


PLAN



PROFILE

NIPMUC RIVER



CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR BY | CK BY

SUBMITTED

APPROVAL RECOMMENDED

WATER RESOURCES STUDY
PASCOAG RIVER
STATION 0+00 TO 62+00
NIPMUC RIVER
STATION 0+00 TO
PLANS AND PROFILES

BURRILLVILLE, RHODE ISLAND

APPROVED DATE

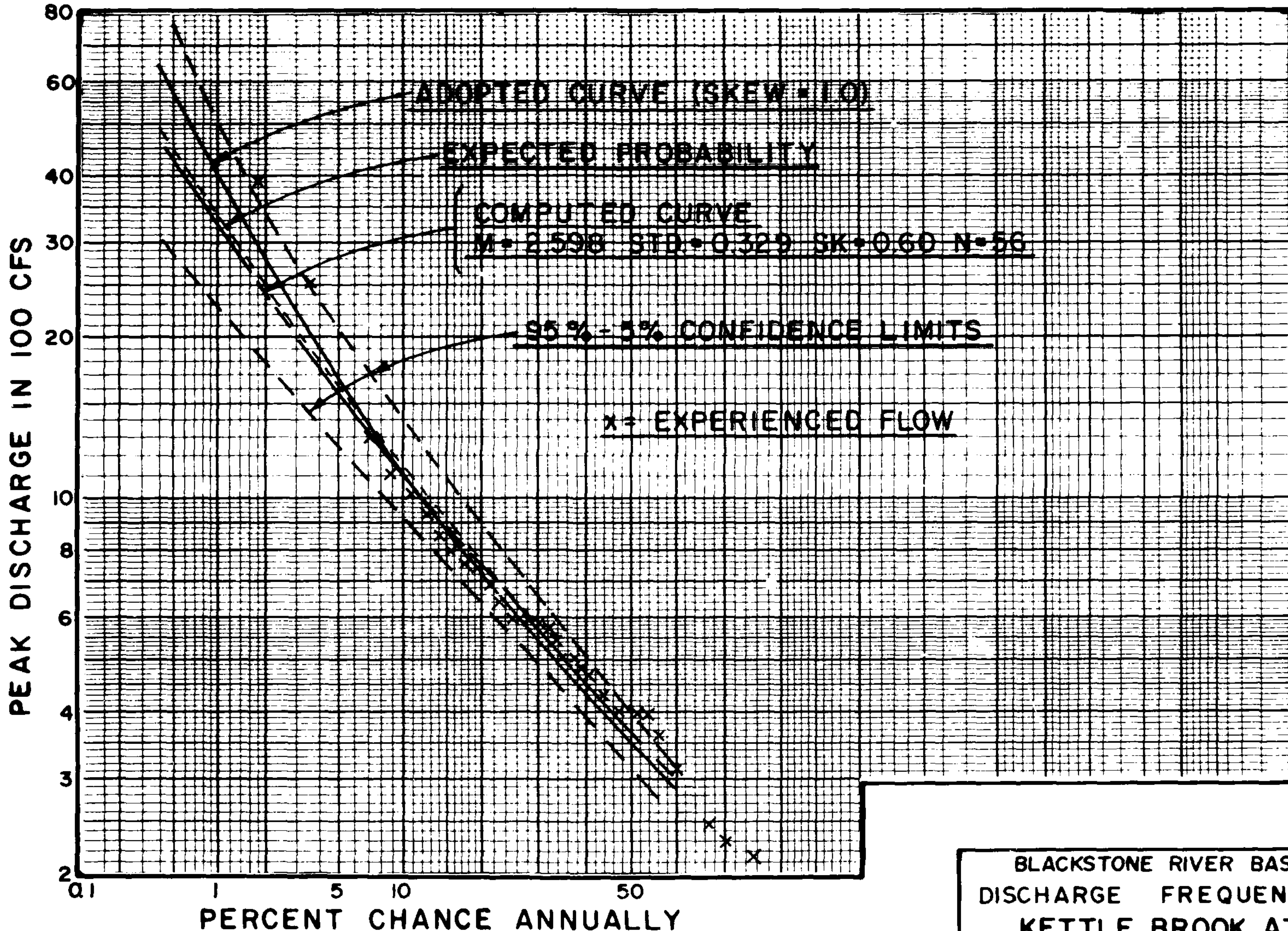
SCALE AS SHOWN SPEC. NO.

DRAWING NUMBER

SHEET 1 of 1

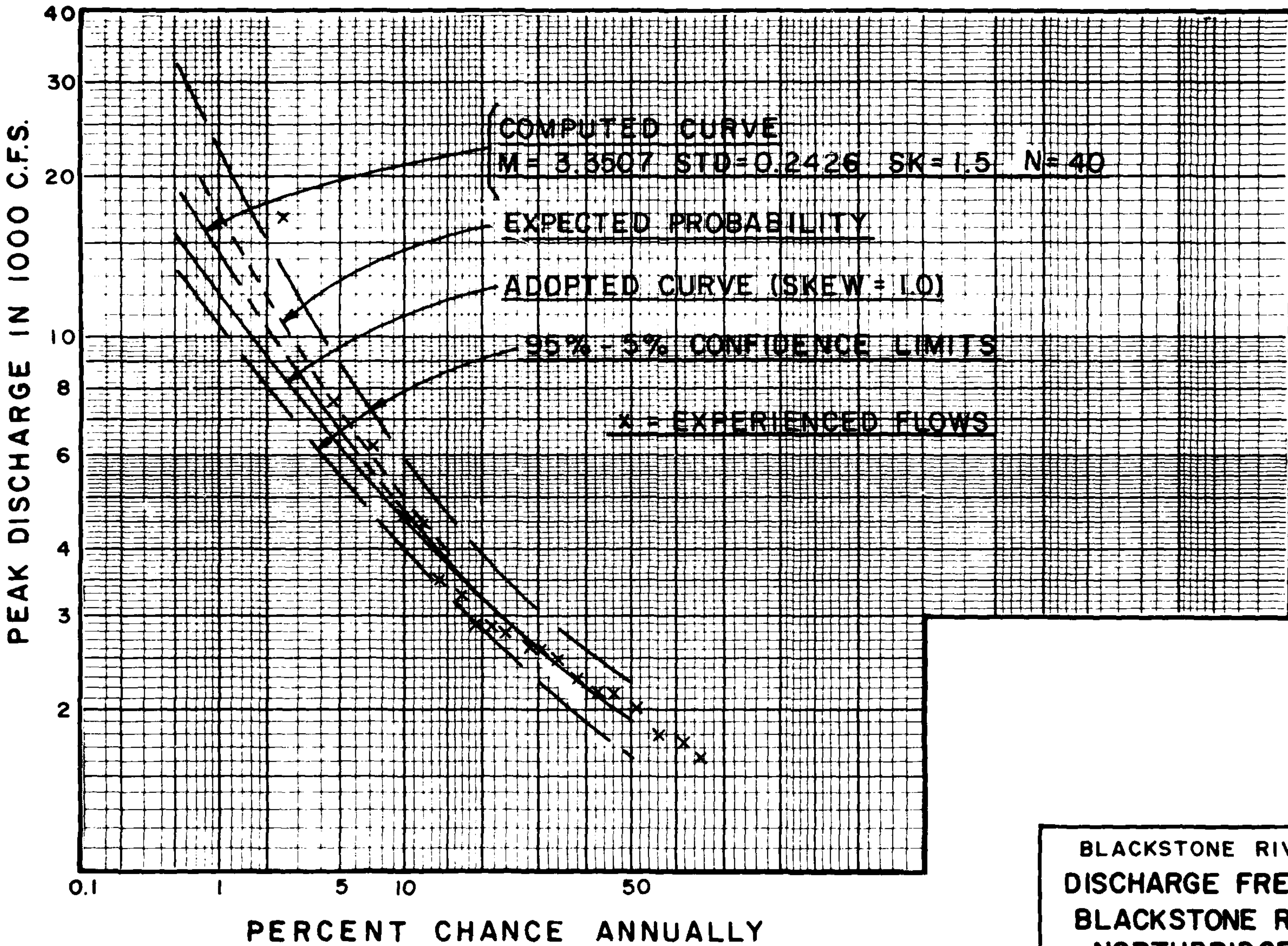
PLATE 14

2



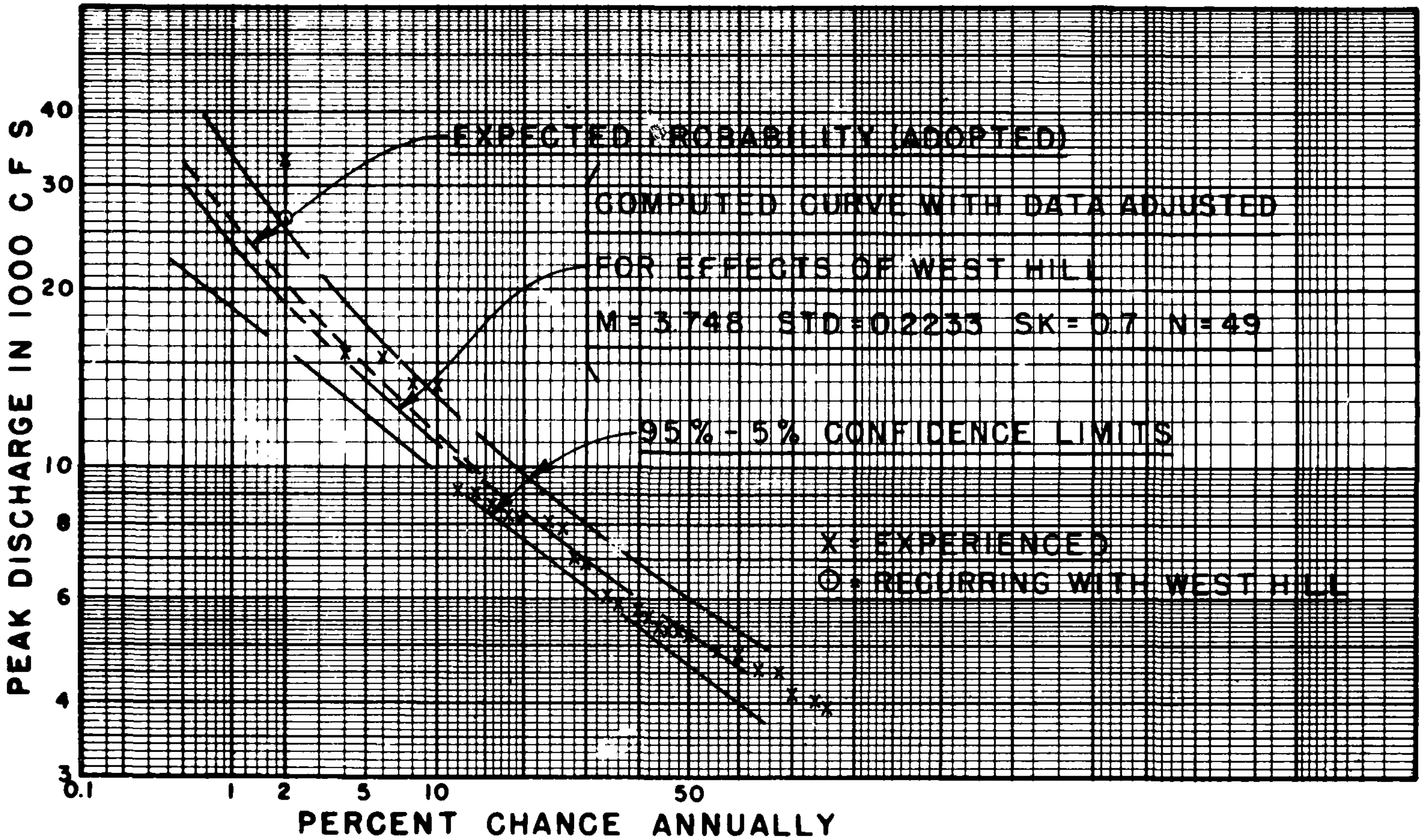
BLACKSTONE RIVER BASIN
DISCHARGE FREQUENCIES
KETTLE BROOK AT
WORCESTER GAGE
D.A. = 31.3 SQ. MILES
MAY 1981

PLATE 15



BLACKSTONE RIVER BASIN
DISCHARGE FREQUENCIES
BLACKSTONE RIVER AT
NORTHBRIDGE GAGE
D.A. = 139 SQ. MILES
MAY 1981

PLATE 16



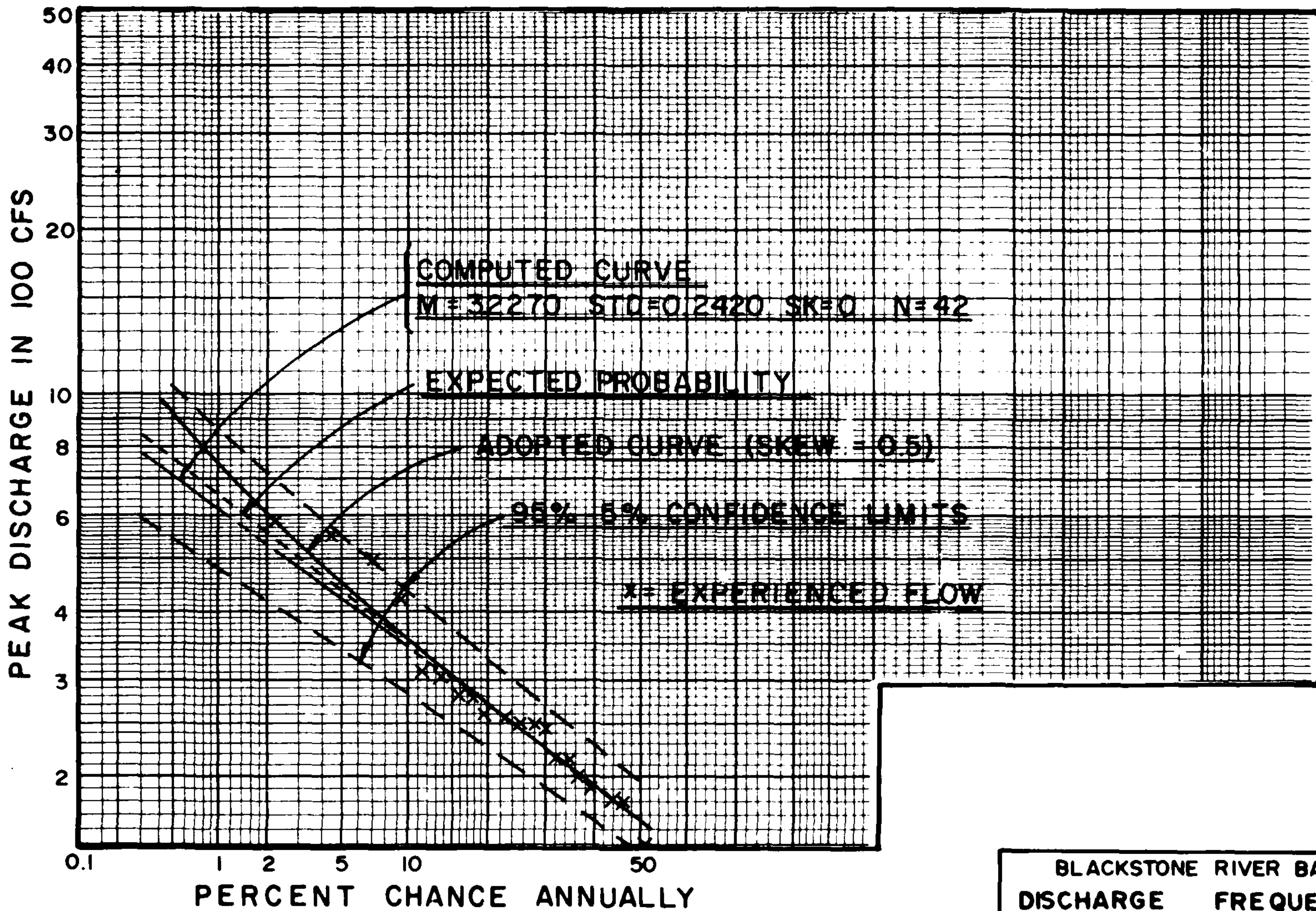
BLACKSTONE RIVER BASIN

DISCHARGE FREQUENCIES

BLACKSTONE RIVER AT WOONSOCKET GAGE

D. A. = 416 SQ. MILES

MAY 1981



BLACKSTONE RIVER BASIN
DISCHARGE FREQUENCIES
BRANCH RIVER AT
FORESTDALE GAGE
D.A. = 91.2 SQ. MILES
MAY 1981

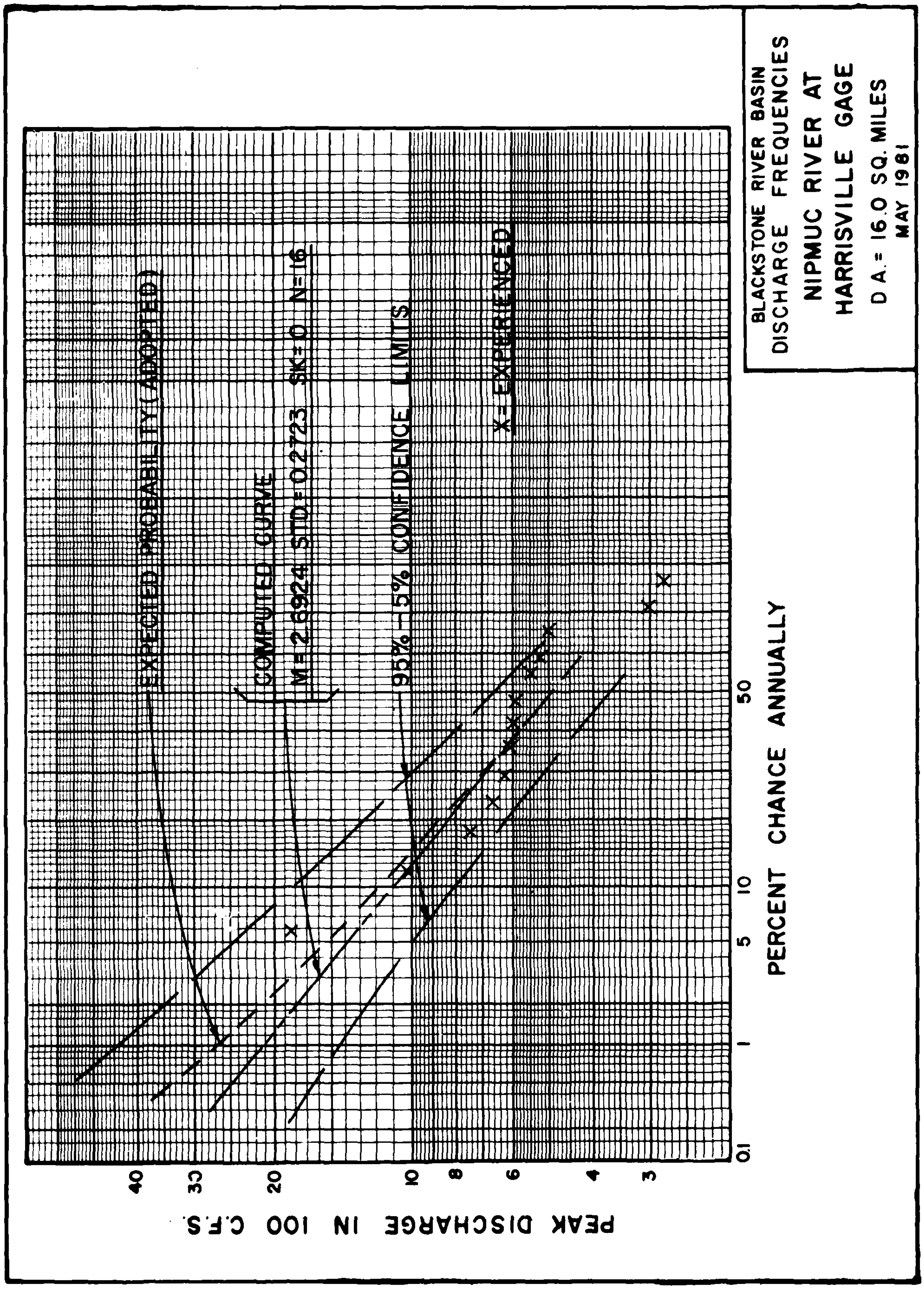
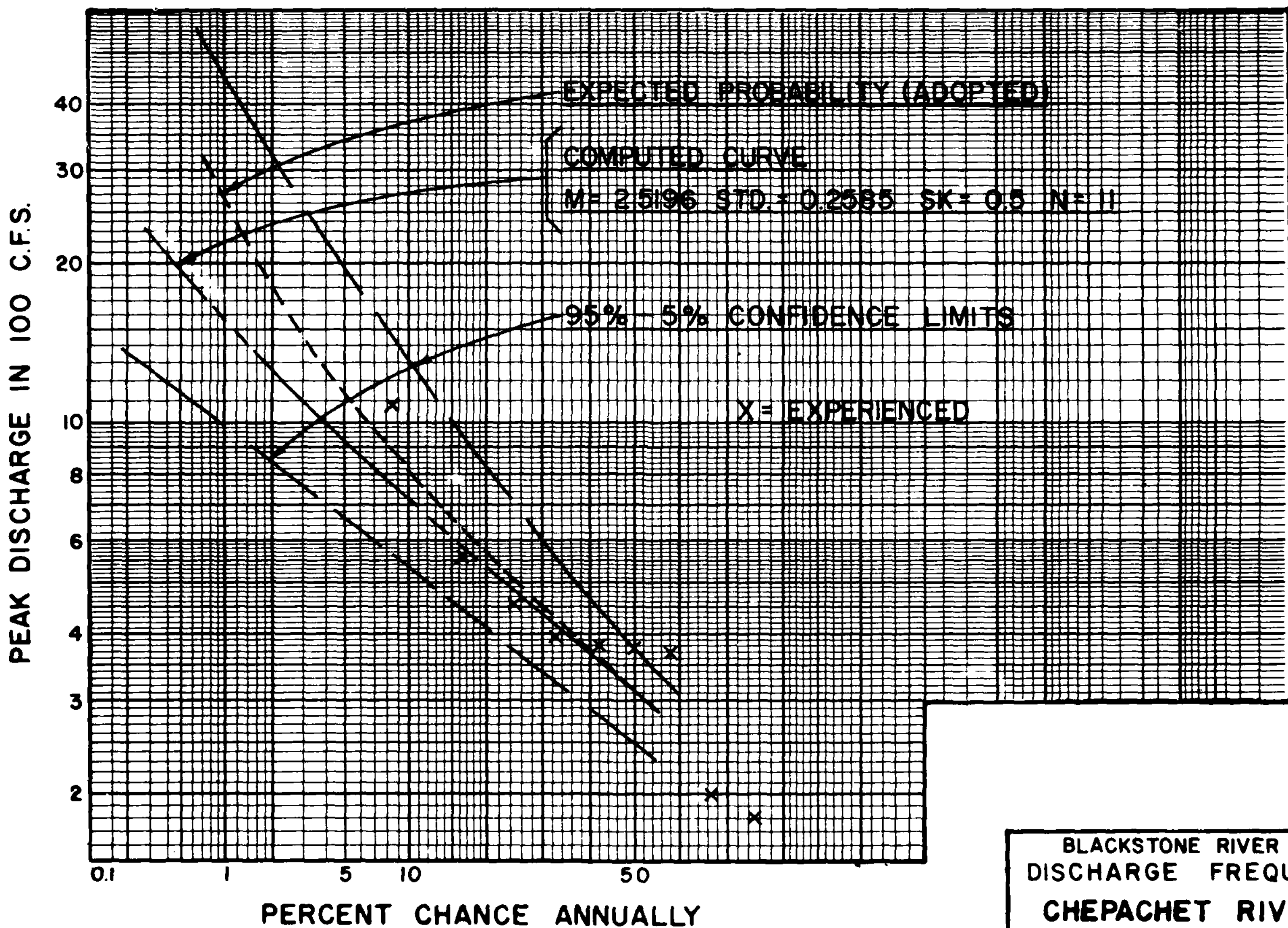

BLACKSTONE RIVER BASIN
DISCHARGE FREQUENCIES
NIPMUC RIVER AT
HARRISVILLE GAGE
D.A.= 16.0 SQ. MILES
MAY 1961
EXPECTED PROBABILITY (ADOPTED)
COMPUTED CURVE
M=2.6924 STD=0.2723 SK=0 N=16
95%-5% CONFIDENCE LIMITS
X-EXPERIENCED
PERCENT CHANCE ANNUALLY
PEAK DISCHARGE IN 100 C.F.S.

PLATE 19

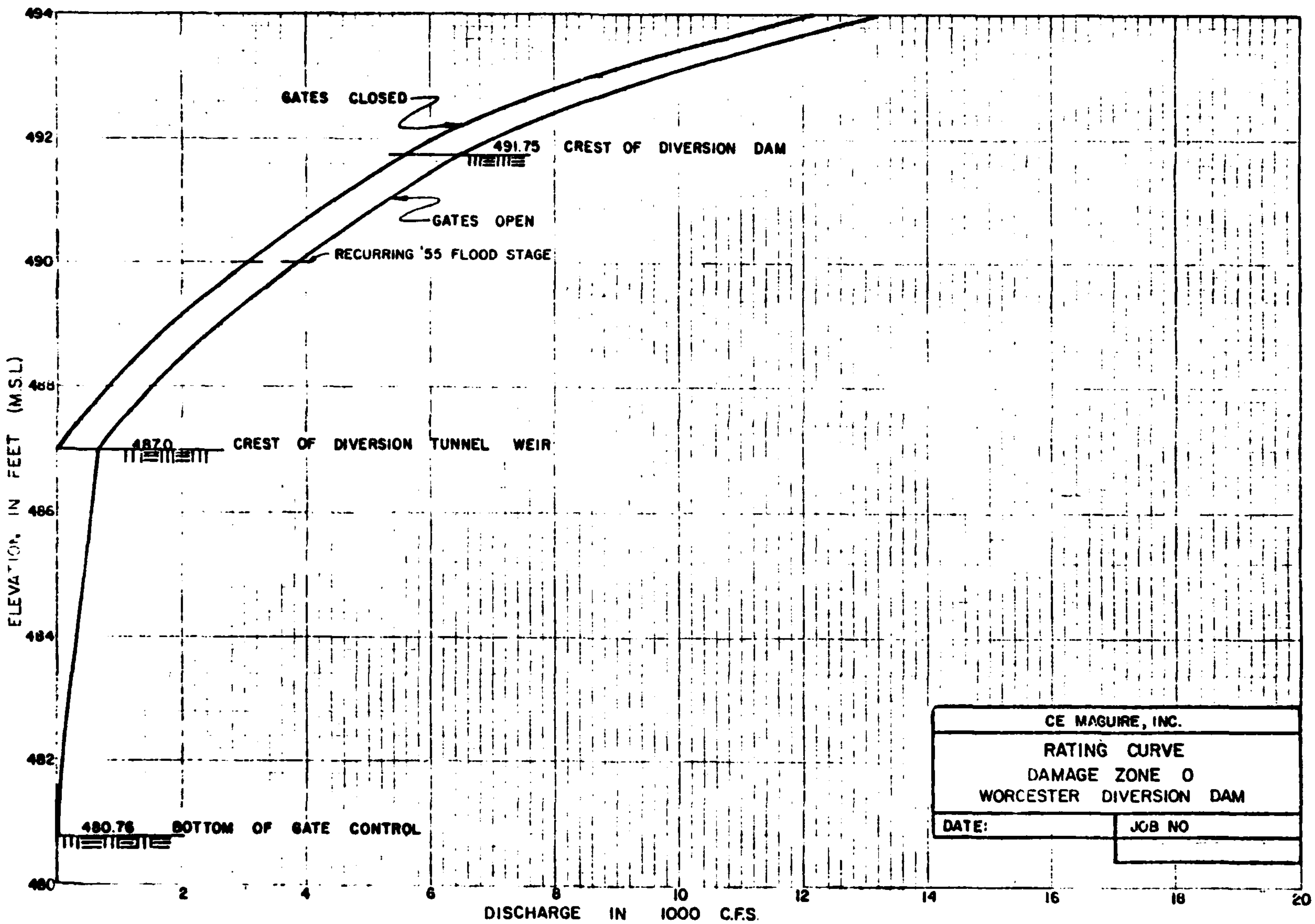


BLACKSTONE RIVER BASIN
DISCHARGE FREQUENCIES

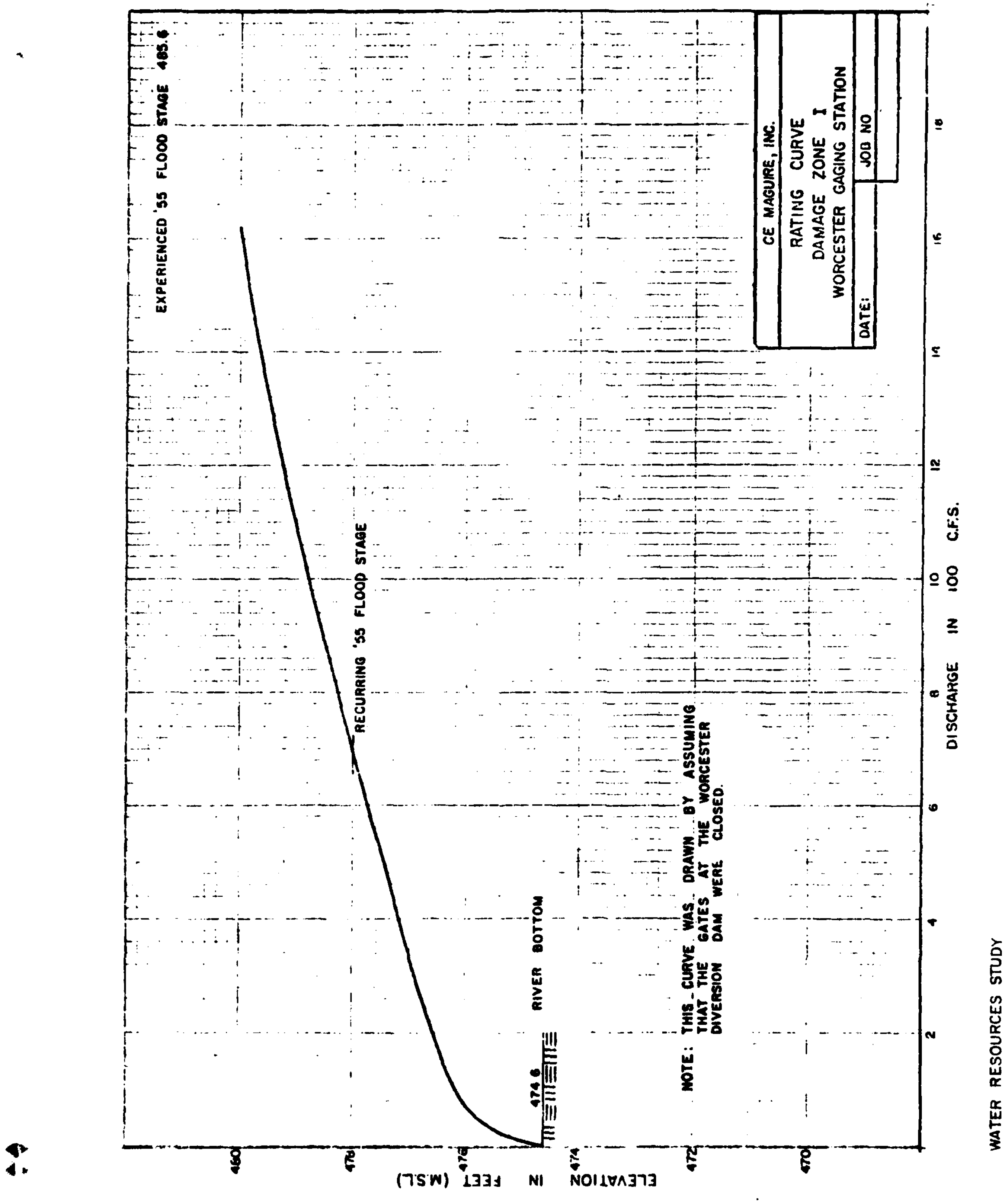
CHEPACHET RIVER AT CHEPACHET GAGE

D.A.= 17.4 SQ. MILES
MAY 1981

PLATE 20

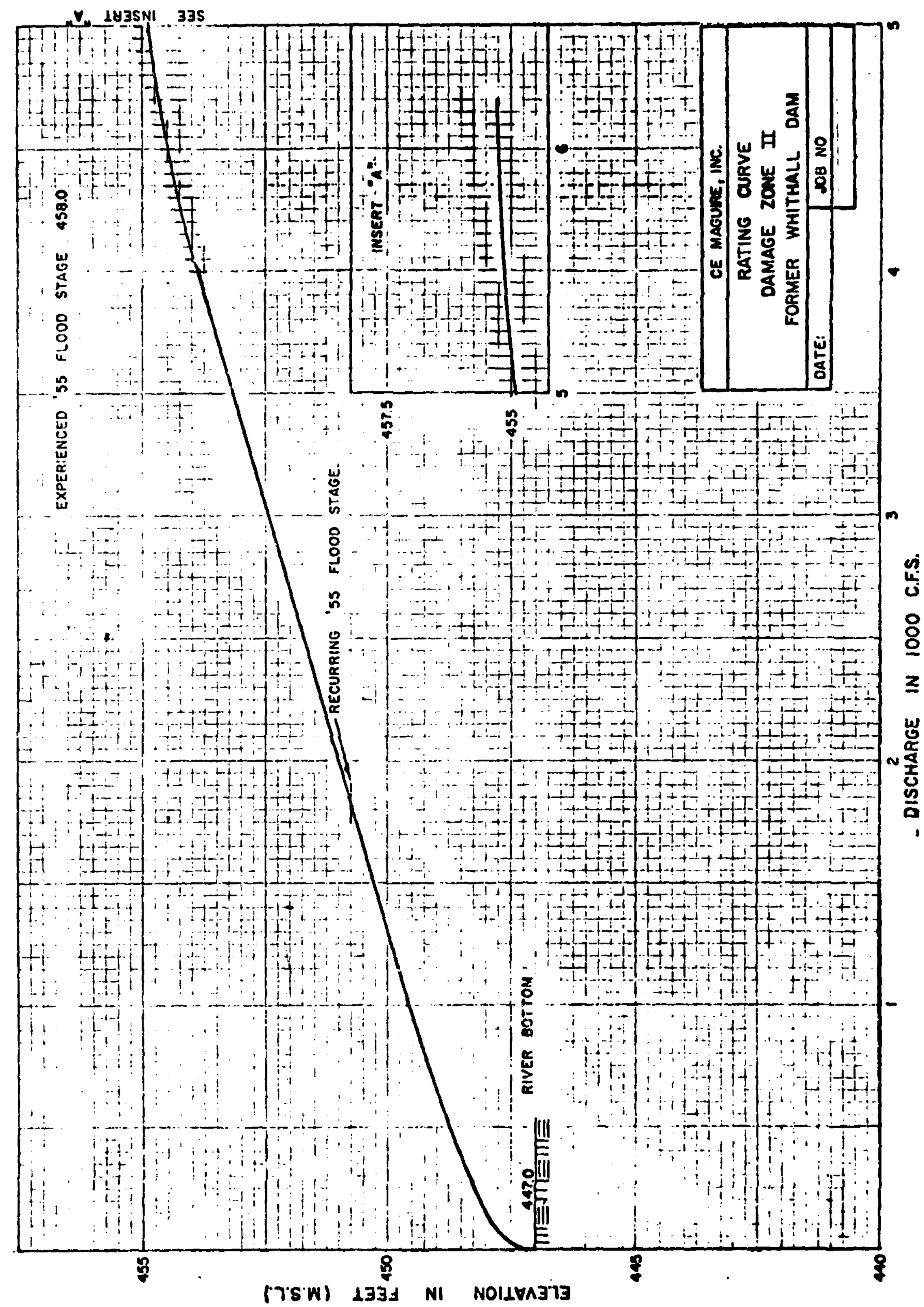


WATER RESOURCES STUDY



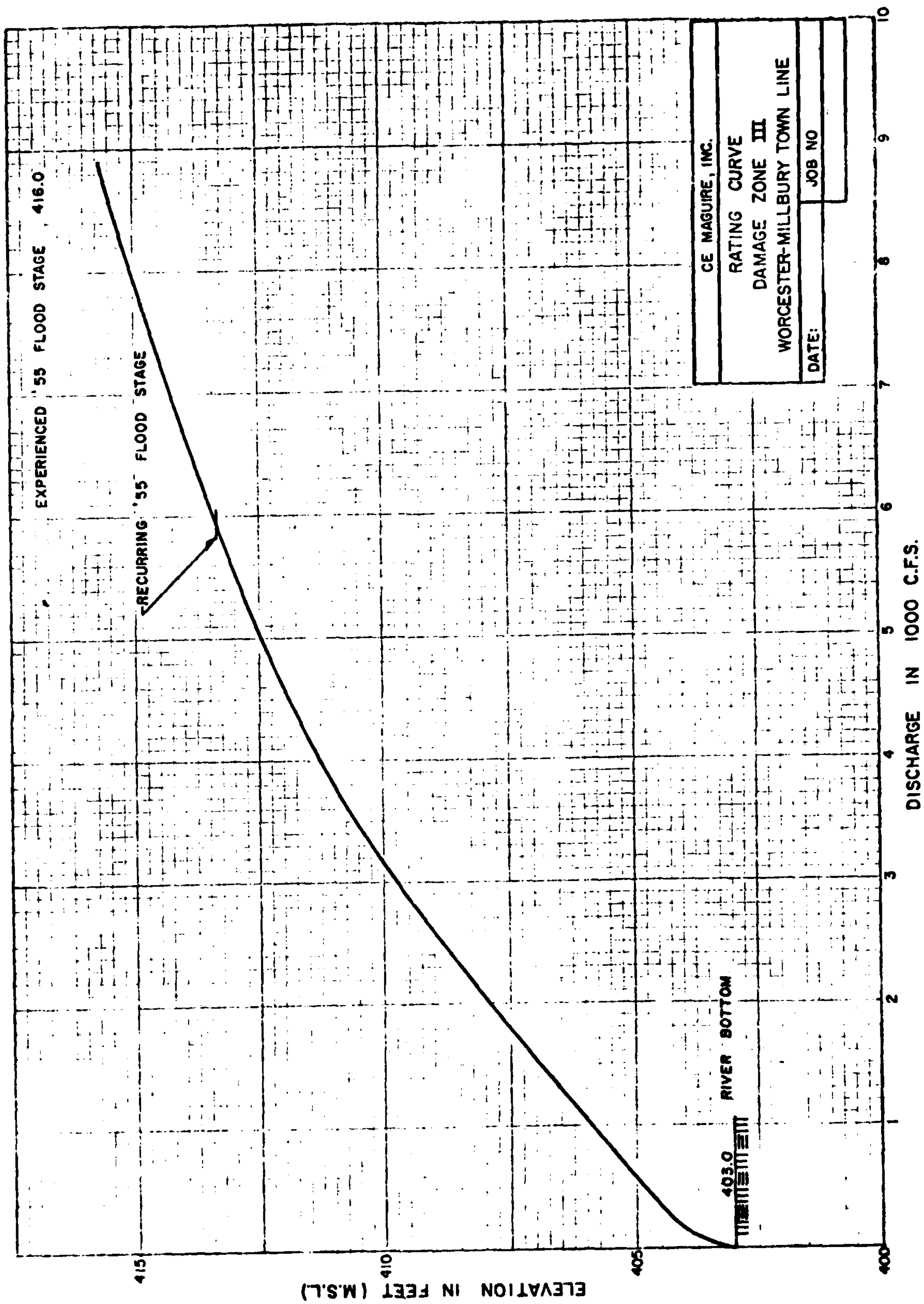
WATER RESOURCES STUDY

PLATE 22



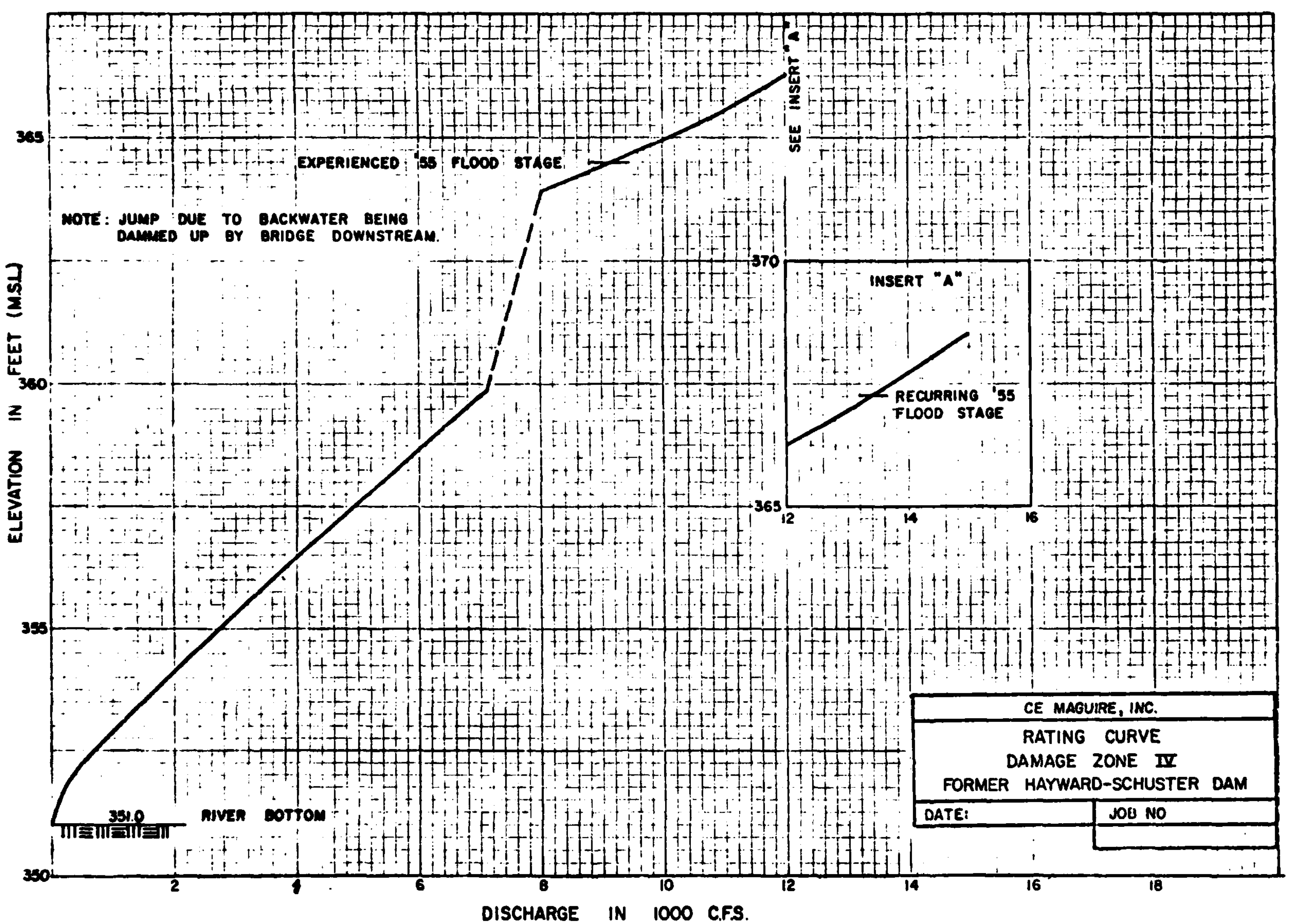
WATER RESOURCES STUDY

PLATE 23

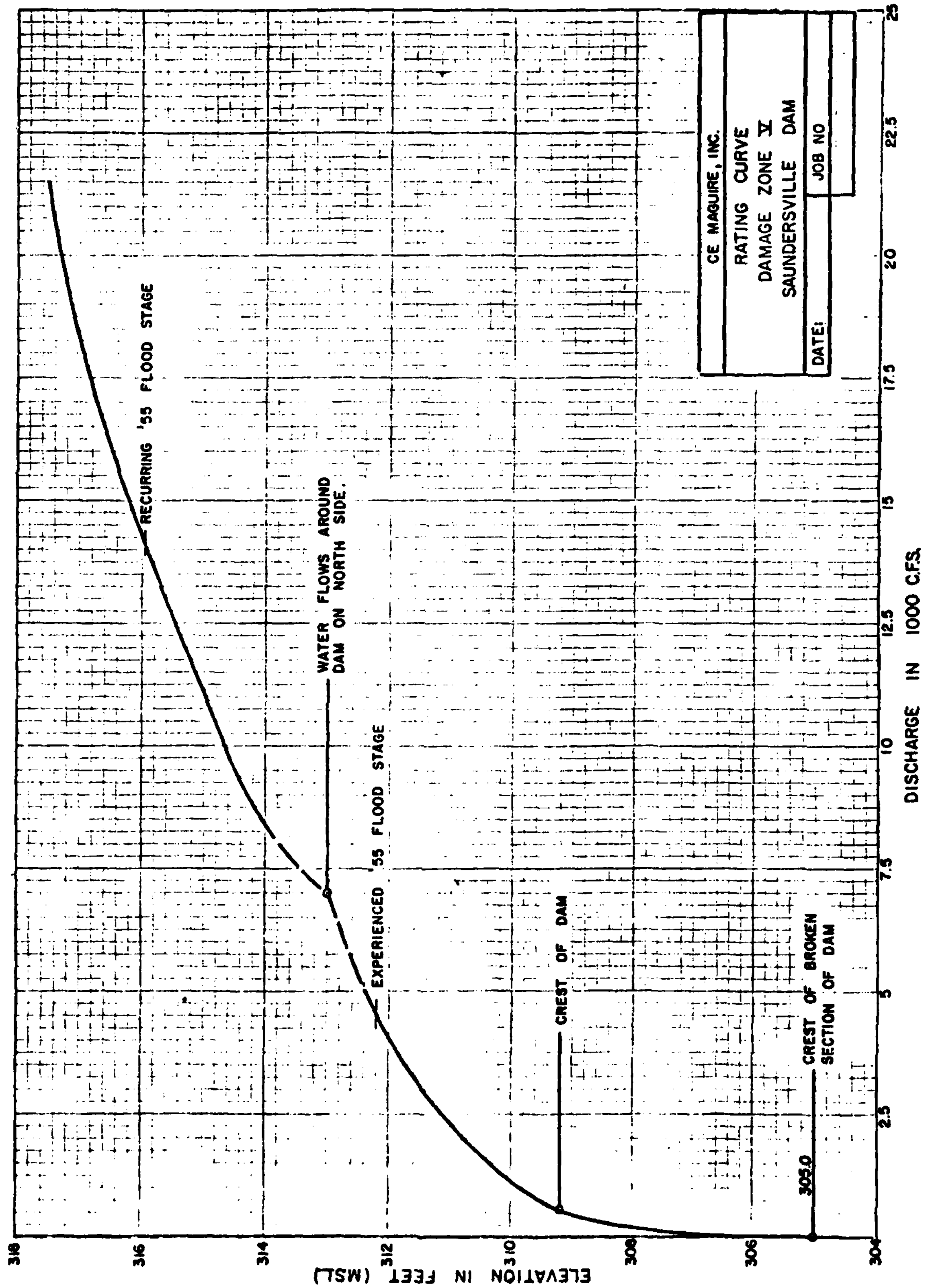


WATER RESOURCES STUDY

PLATE 24

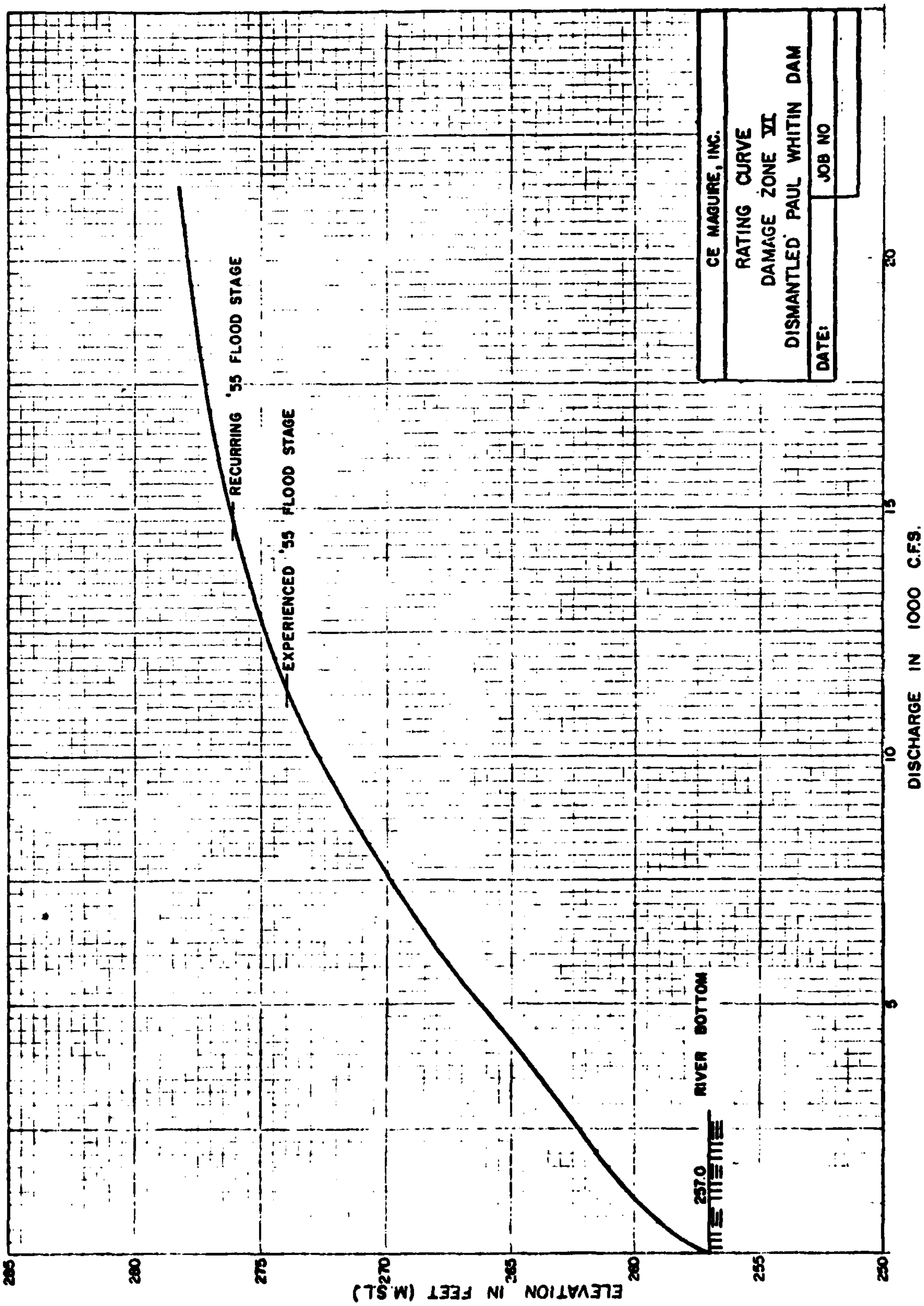


WATER RESOURCES STUDY

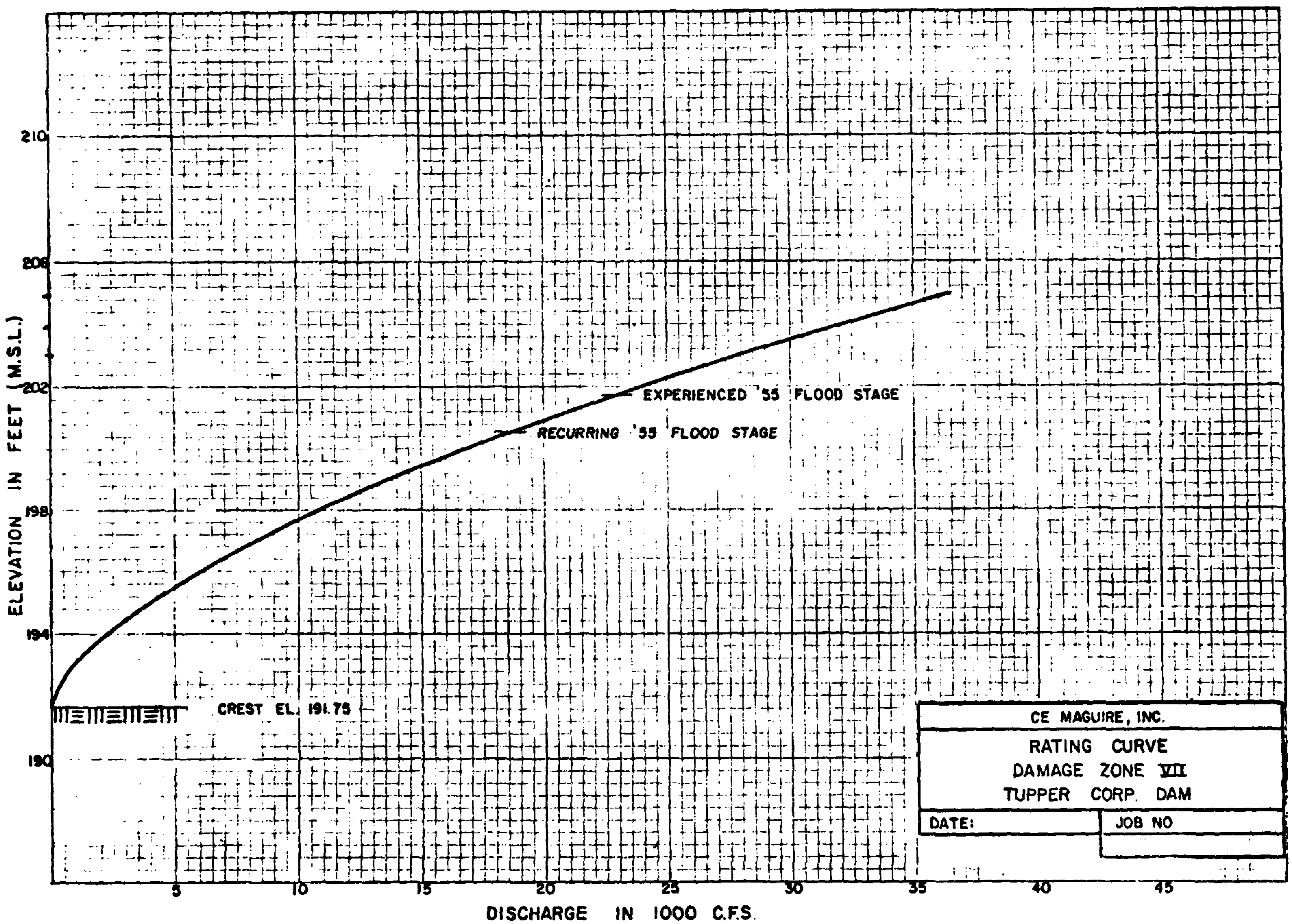


WATER RESOURCES STUDY

PLATE 26

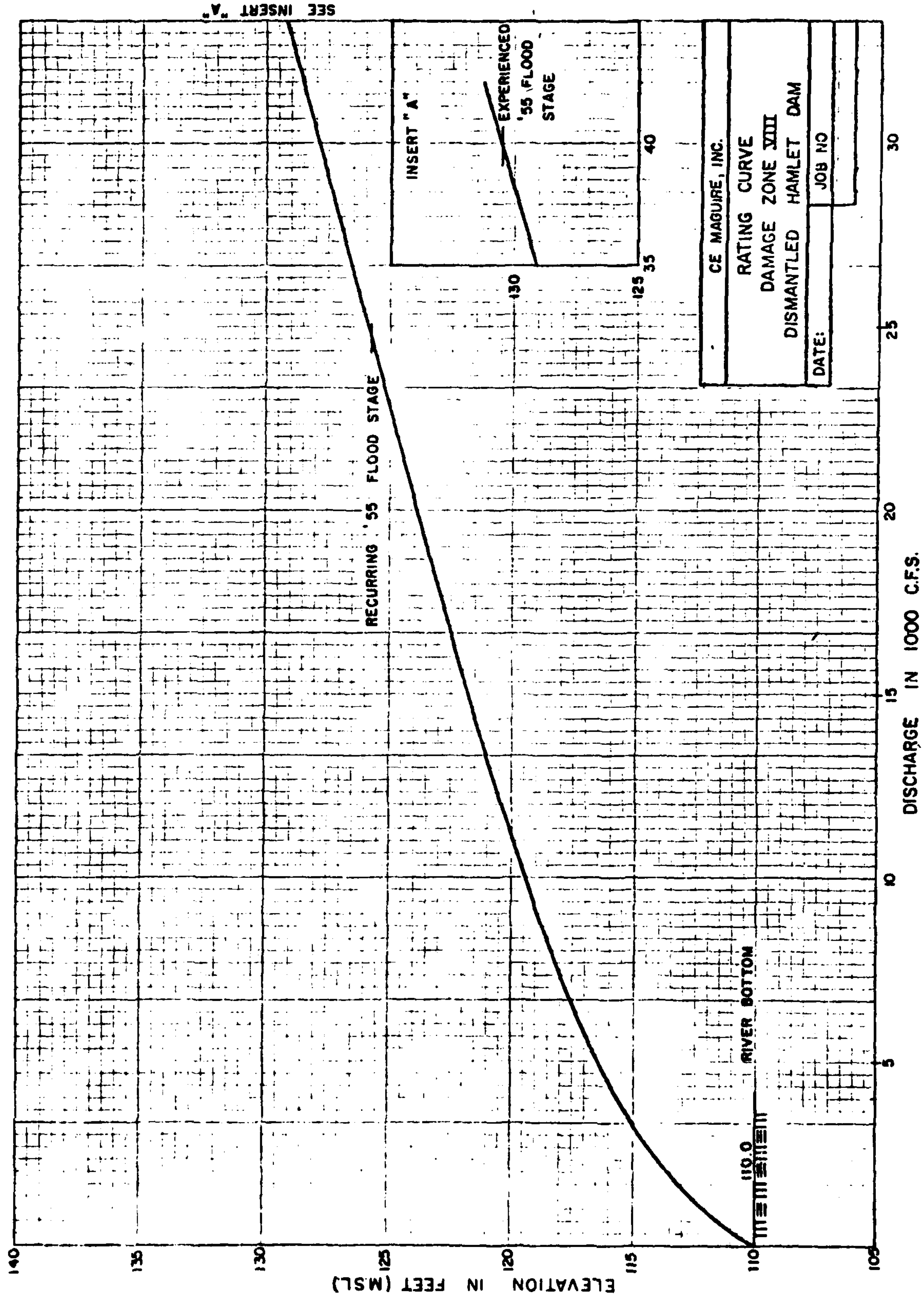


WATER RESOURCES STUDY



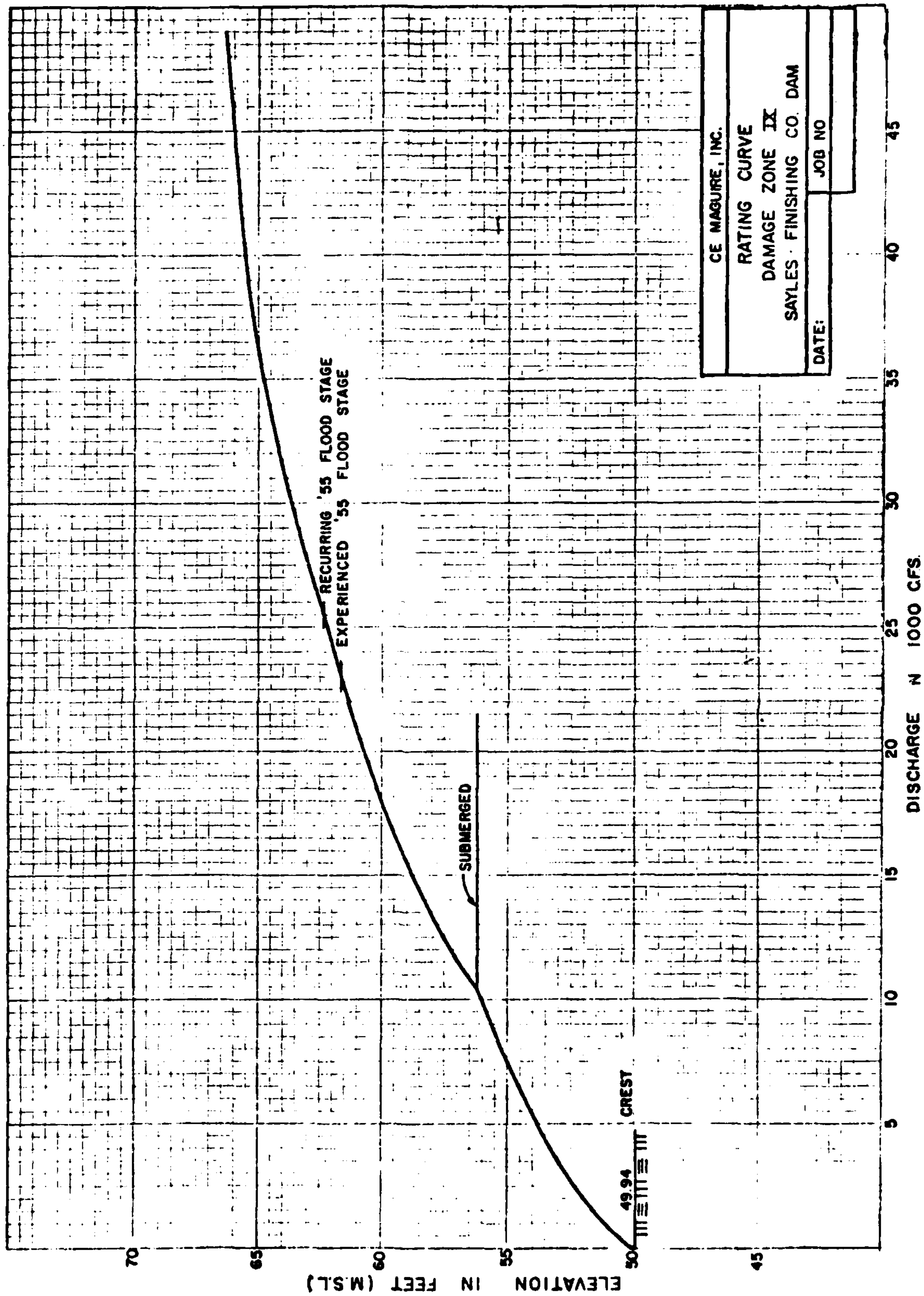
WATER RESOURCES STUDY

PLATE 28



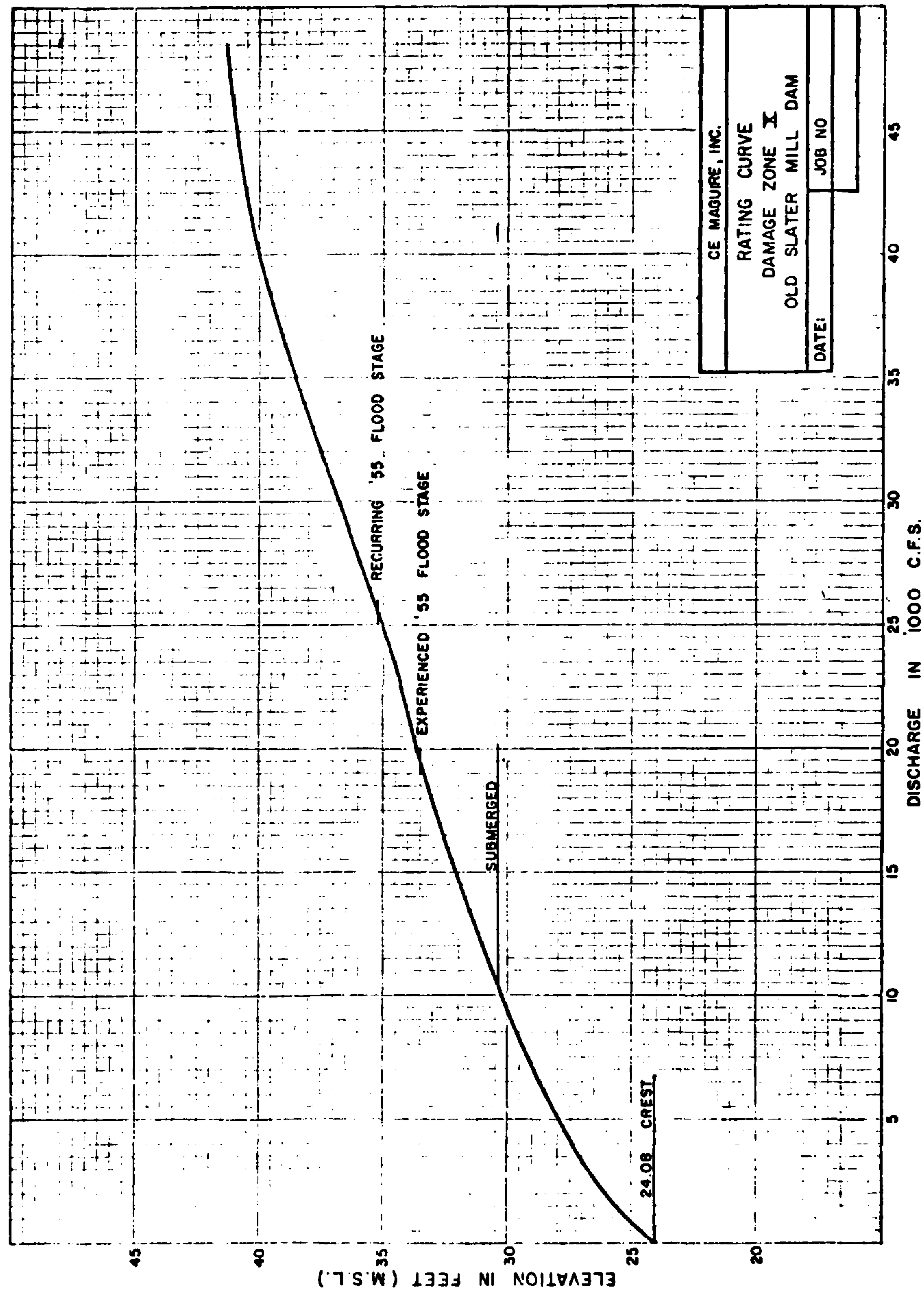
WATER RESOURCES STUDY

PLATE 29



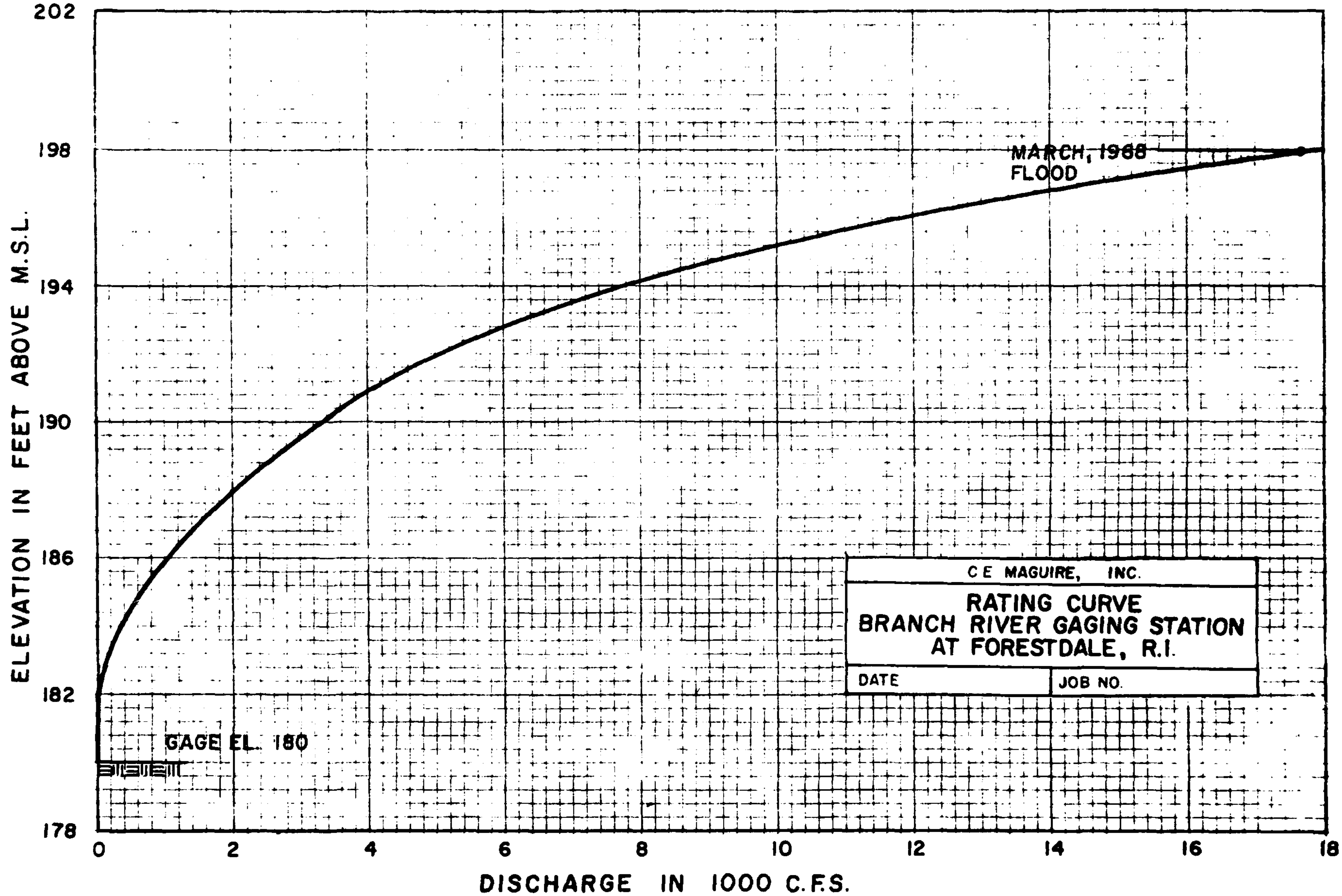
WATER RESOURCES STUDY

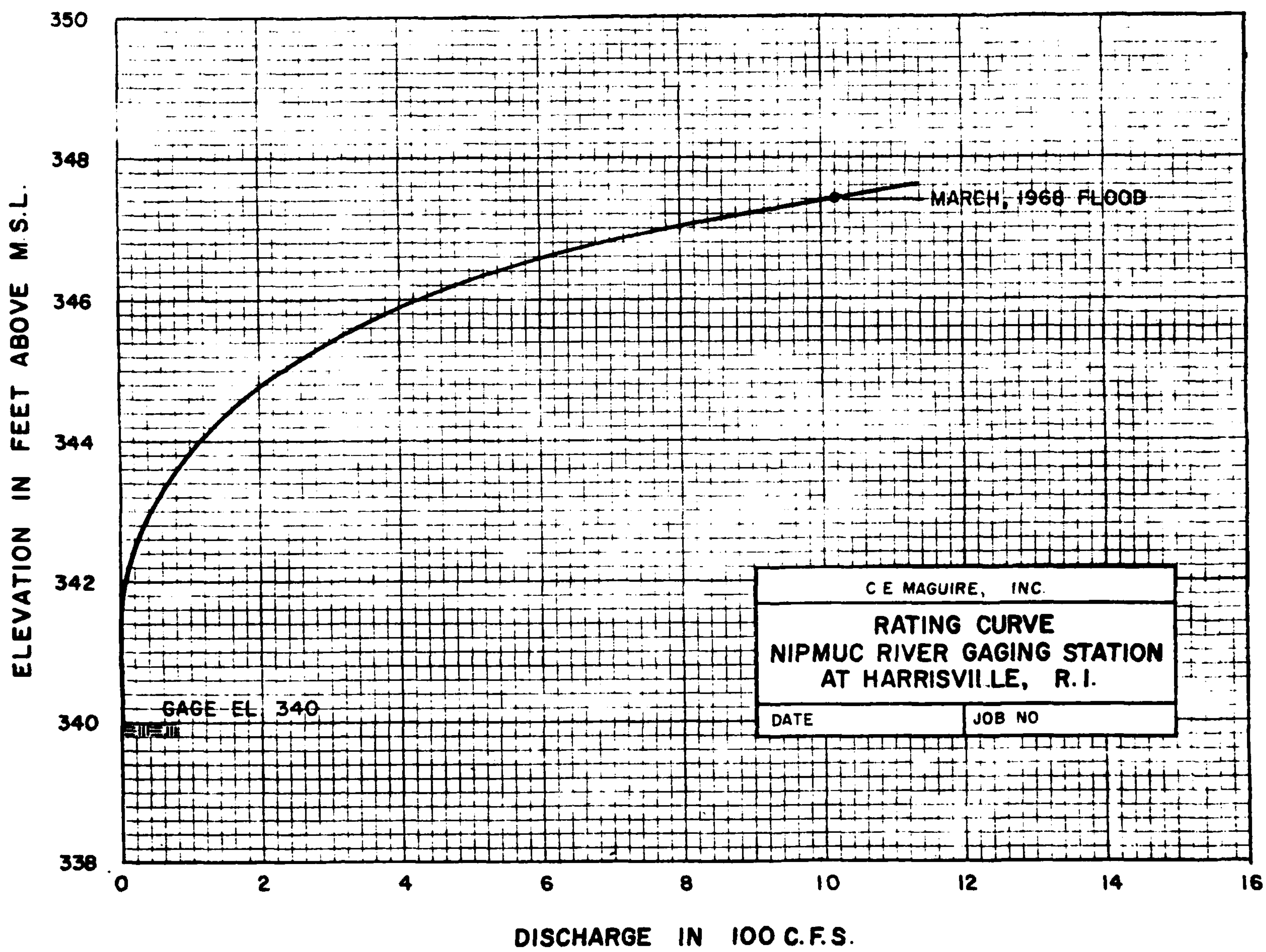
PLATE 30



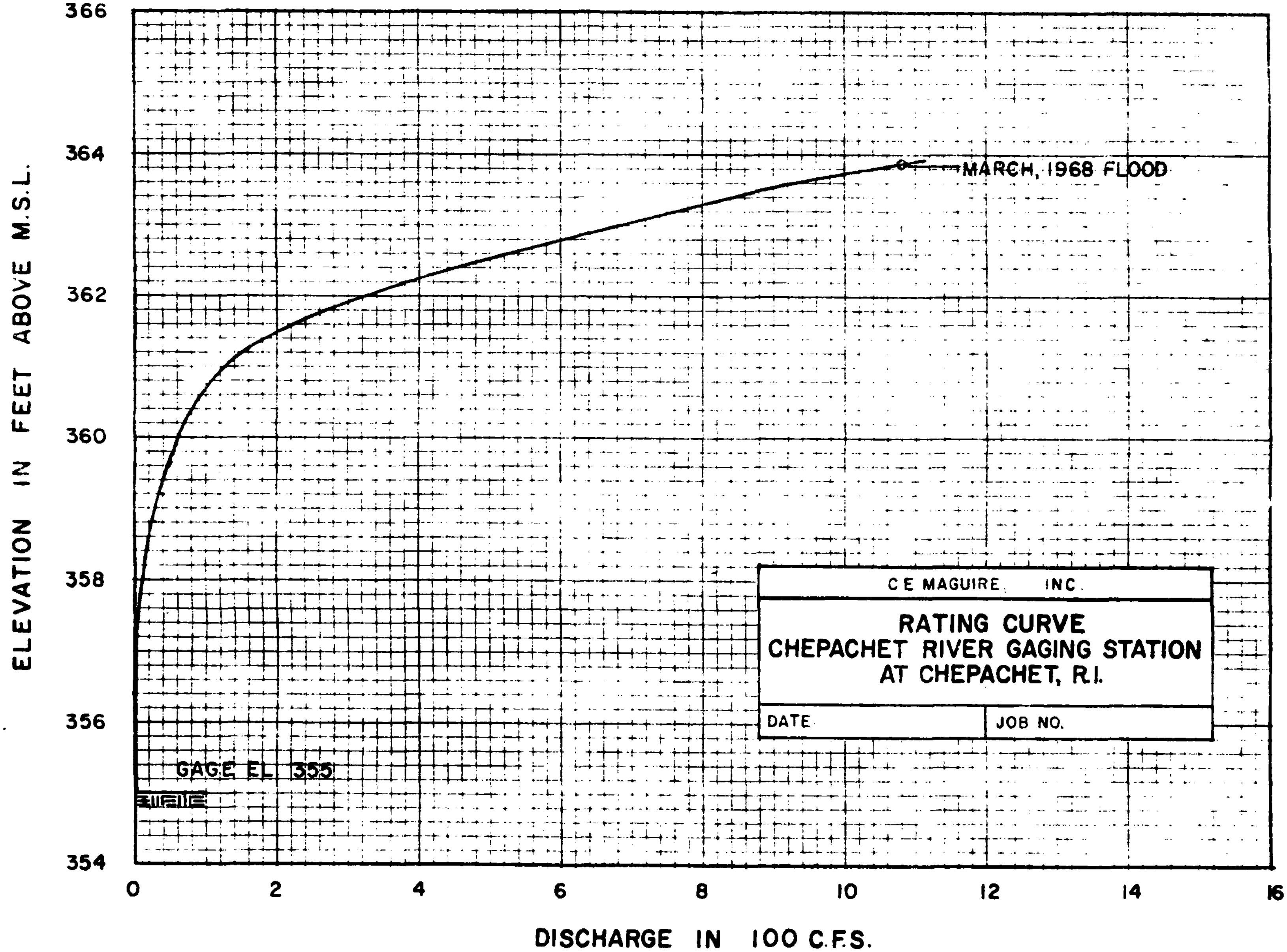
WATER RESOURCES STUDY

PLATE 31

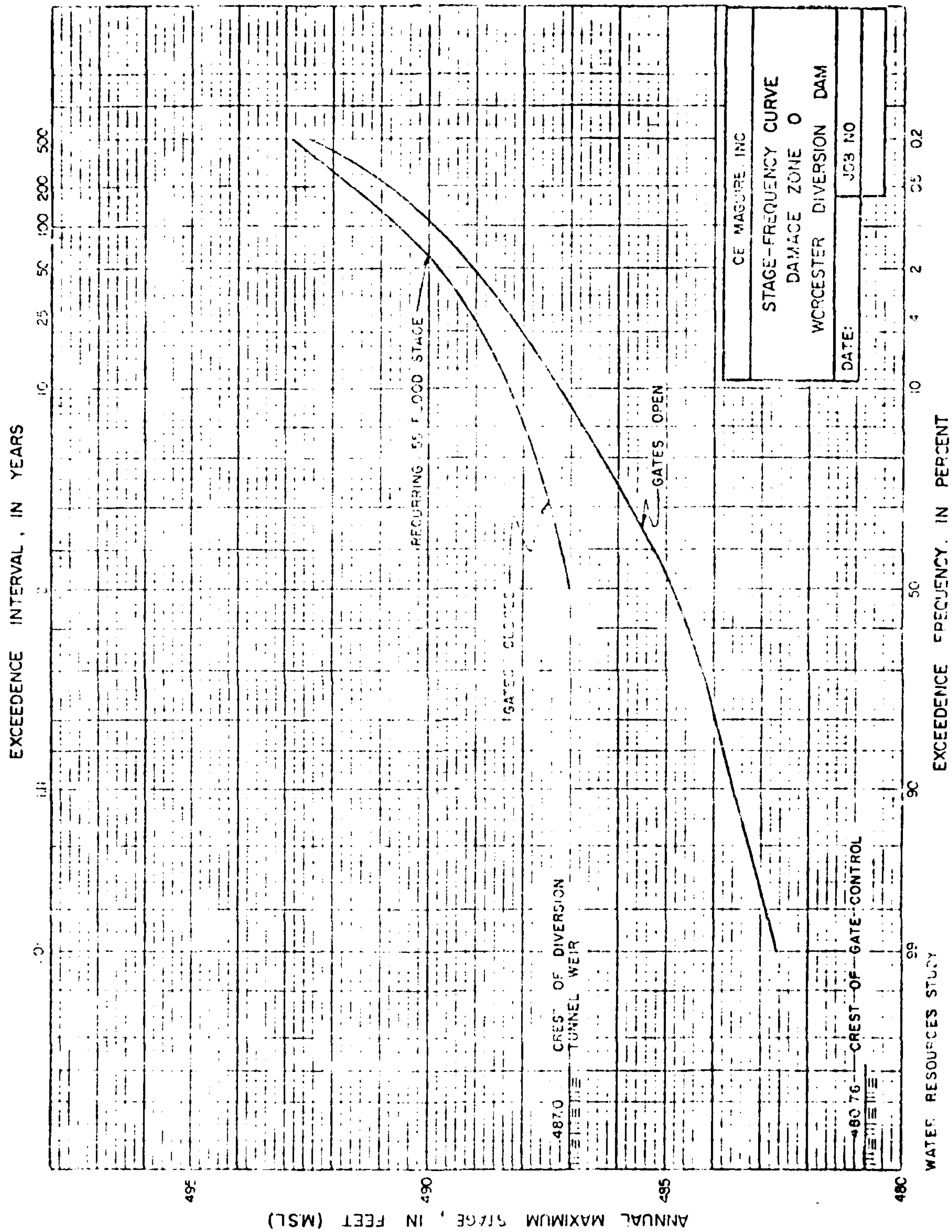

C E MAGUIRE, INC.
RATING CURVE
BRANCH RIVER GAGING STATION
AT FORESTDALE, R.I.
DATE
JOB NO.
MARCH, 1968
FLOOD
GAGE EL. 180
ELEVATION IN FEET ABOVE M.S.L.
202
198
194
190
186
182
178
0
2
4
6
8
10
12
14
16
18
DISCHARGE IN 1000 C.F.S.



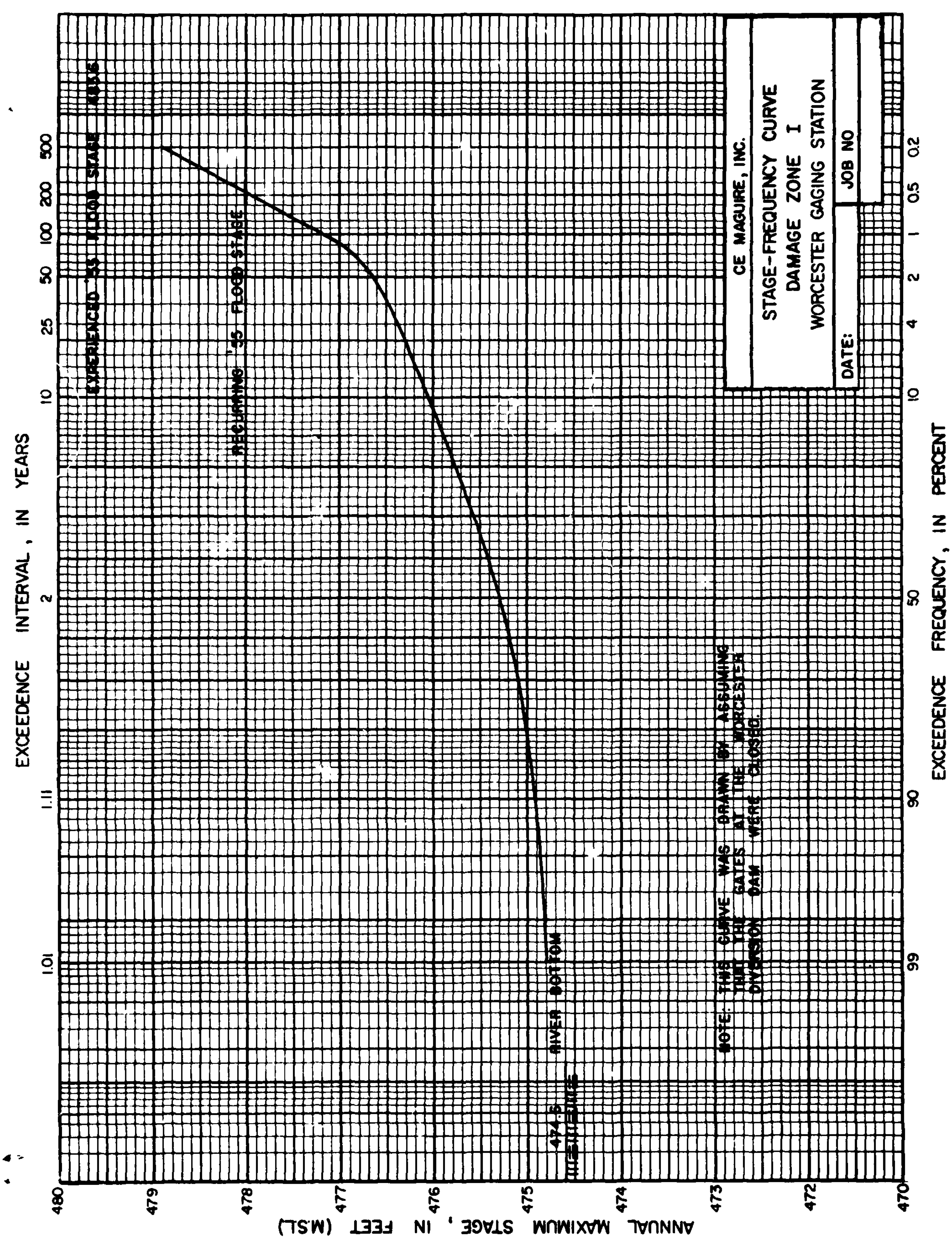
WATER RESOURCES STUDY



WATER RESOURCES STUDY



EXCEEDENCE INTERVAL, IN YEARS
EXCEEDENCE FREQUENCY, IN PERCENT
ANNUAL MAXIMUM STAGE, IN FEET (MSL)
RECURRING 55 FLOOD STAGE
GATES OPEN
GATES CLOSED
CREST OF DIVERSION TUNNEL WEIR
487.0
480.76
CREST-OF-GATE-CONTROL
CE MAGUIRE INC
STAGE-FREQUENCY CURVE
DAMAGE ZONE O
WORCESTER DIVERSION DAM
DATE:
JOB NO
WATER RESOURCES STUDY


EXCEEDENCE INTERVAL, IN YEARS
1.01
1.11
2
10
25
50
100
200
500
EXCEEDENCE FREQUENCY, IN PERCENT
99
90
50
10
4
2
1
0.5
0.2
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L.)
470
471
472
473
474
475
476
477
478
479
480
EXPERIENCED '55 FLOOD STAGE 485.6
RECURRING '55 FLOOD STAGE
RIVER BOTTOM
474.5
NOTE: THIS CURVE WAS DRAWN BY ASSUMING
THAT THE GATES AT THE WORCESTER
DIVERSION DAM WERE CLOSED.
CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE I
WORCESTER GAGING STATION
DATE:
JOB NO

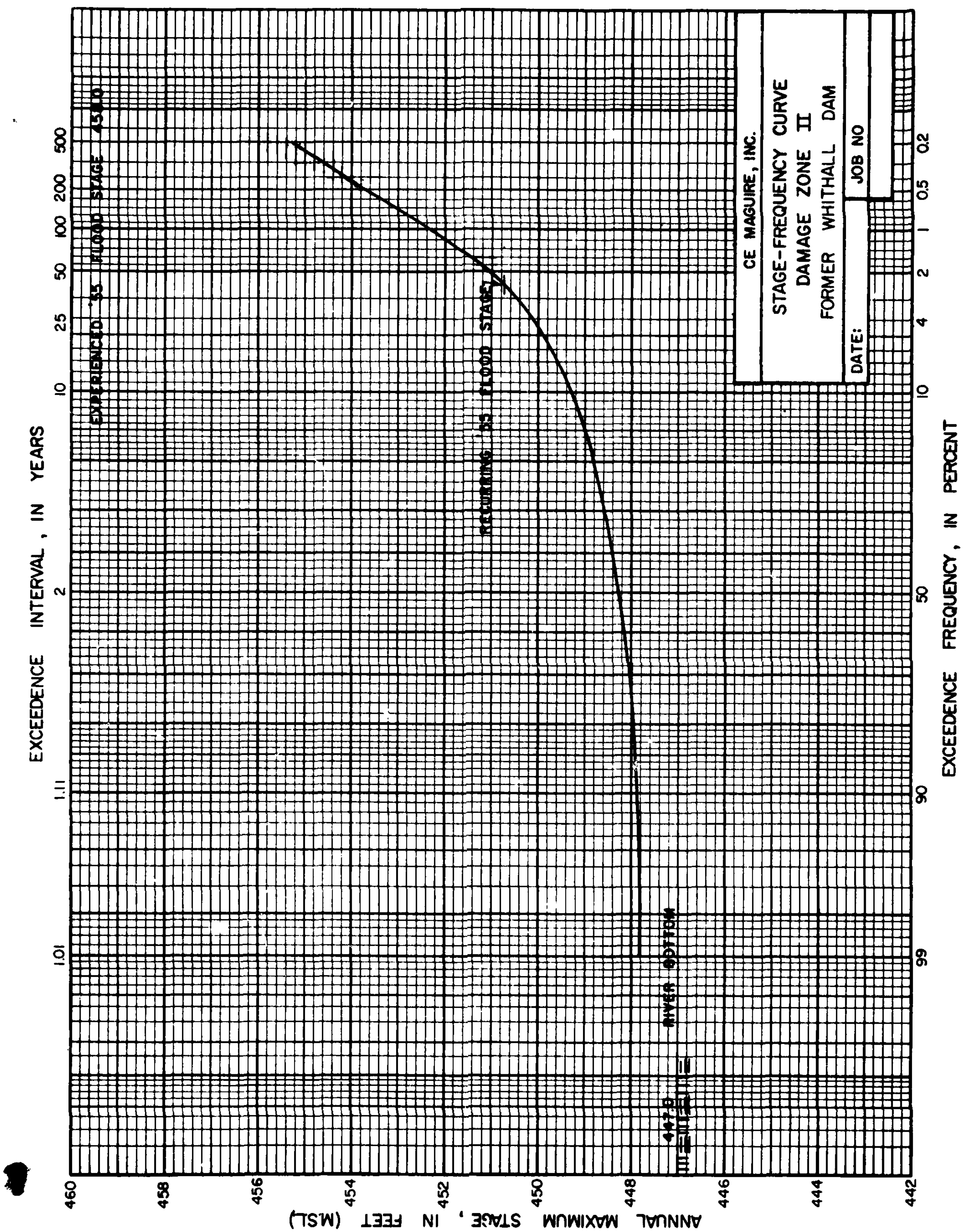

CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE II
FORMER WHITHALL DAM
DATE:
JOB NO
EXCEEDENCE INTERVAL, IN YEARS
1.01
1.11
2
10
25
50
100
200
500
EXCEEDENCE FREQUENCY, IN PERCENT
99
90
50
10
4
2
1
0.5
0.2
ANNUAL MAXIMUM STAGE, IN FEET (MSL)
460
458
456
454
452
450
448
446
444
442
EXPERIENCED '55 FLOOD STAGE 458.0
RECURRING '55 FLOOD STAGE
RIVER BOTTOM
447.0

PLATE 37

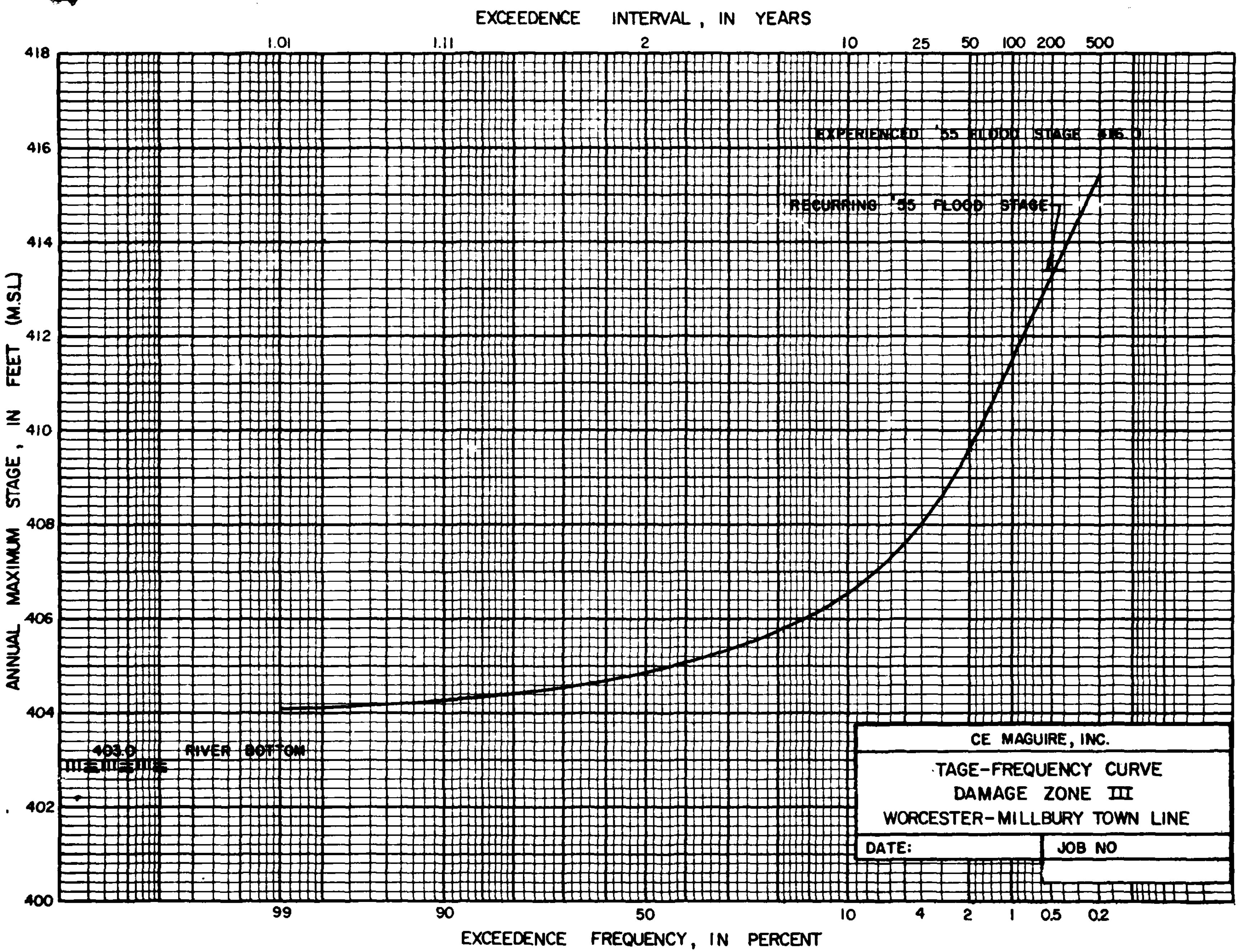

EXCEEDENCE INTERVAL, IN YEARS
1.01
1.11
2
10
25
50
100
200
500
418
416
414
412
410
408
406
404
402
400
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L)
EXPERIENCED '55 FLOOD STAGE 416.0
RECURRING '55 FLOOD STAGE
403.0
RIVER BOTTOM
99
90
50
10
4
2
1
0.5
0.2
EXCEEDENCE FREQUENCY, IN PERCENT
CE MAGUIRE, INC.
TAGE-FREQUENCY CURVE
DAMAGE ZONE III
WORCESTER-MILLBURY TOWN LINE
DATE:
JOB NO

PLATE 38

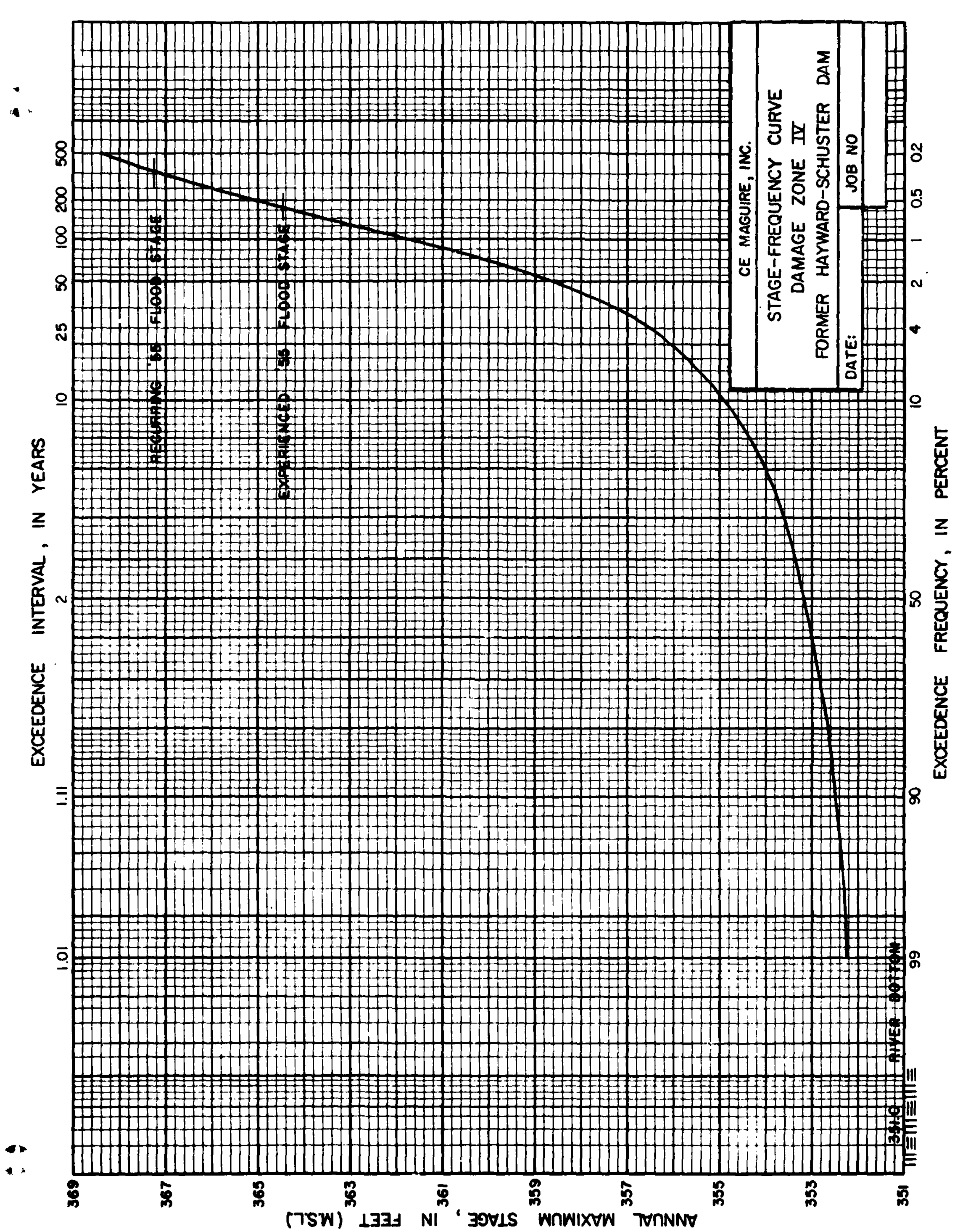
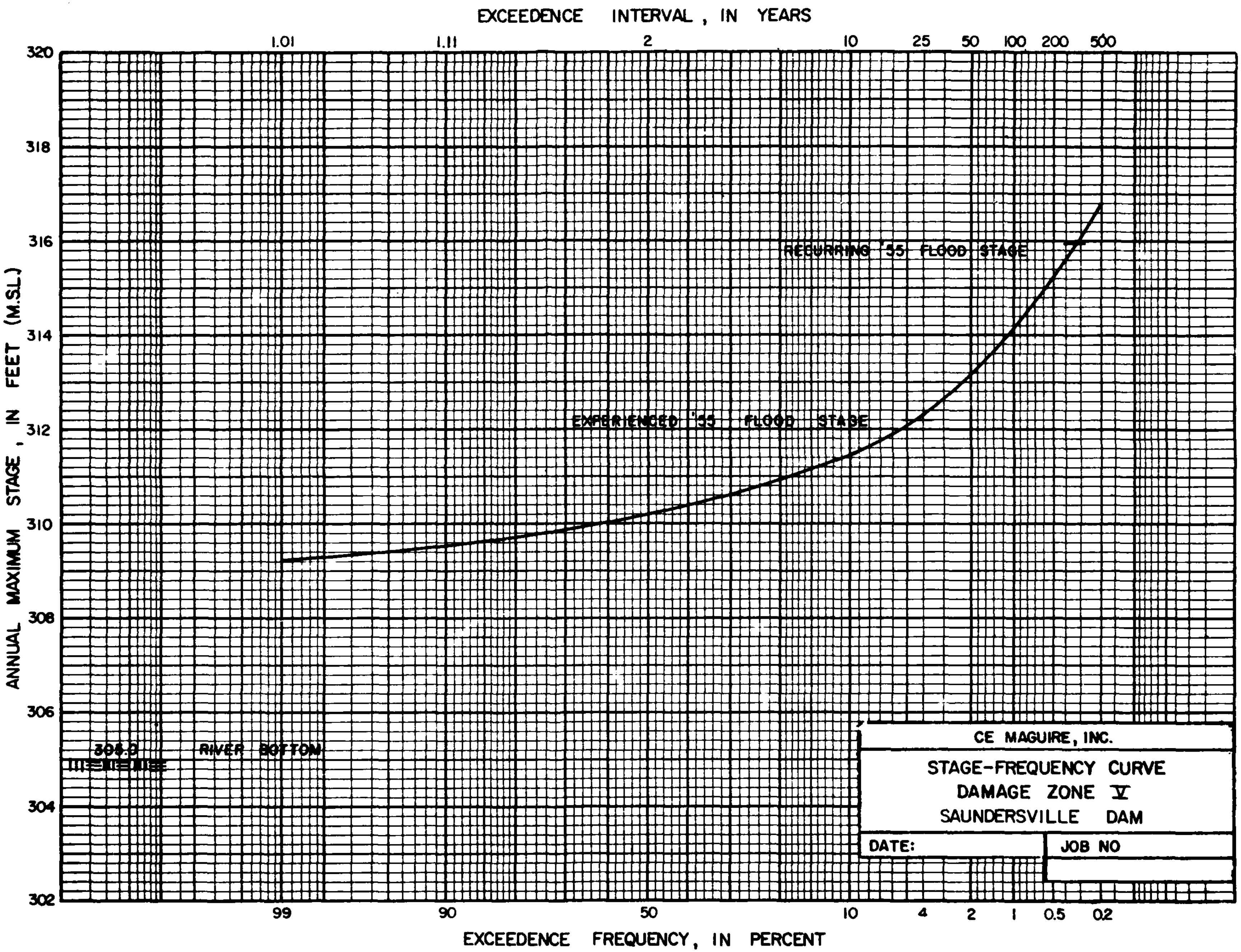
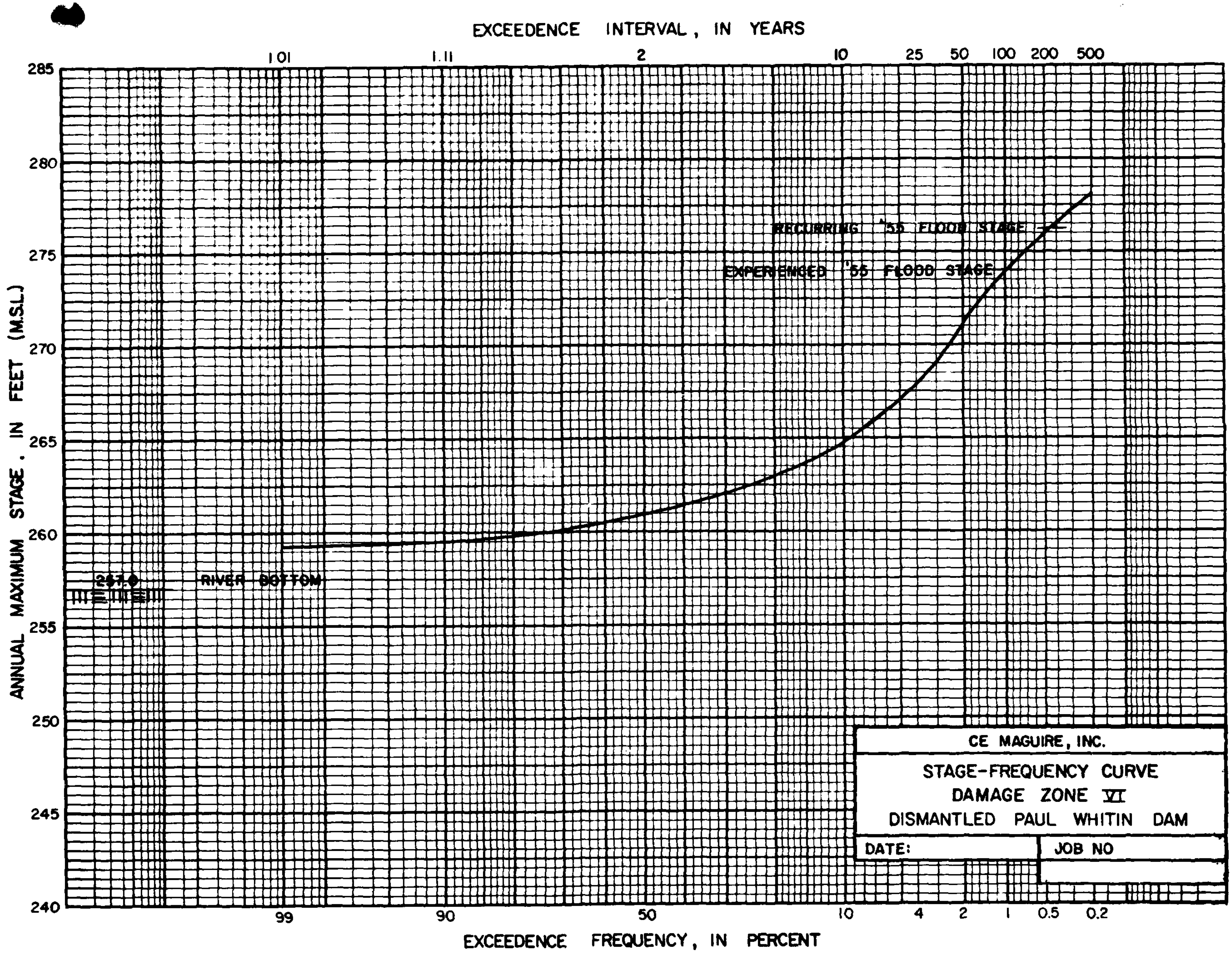
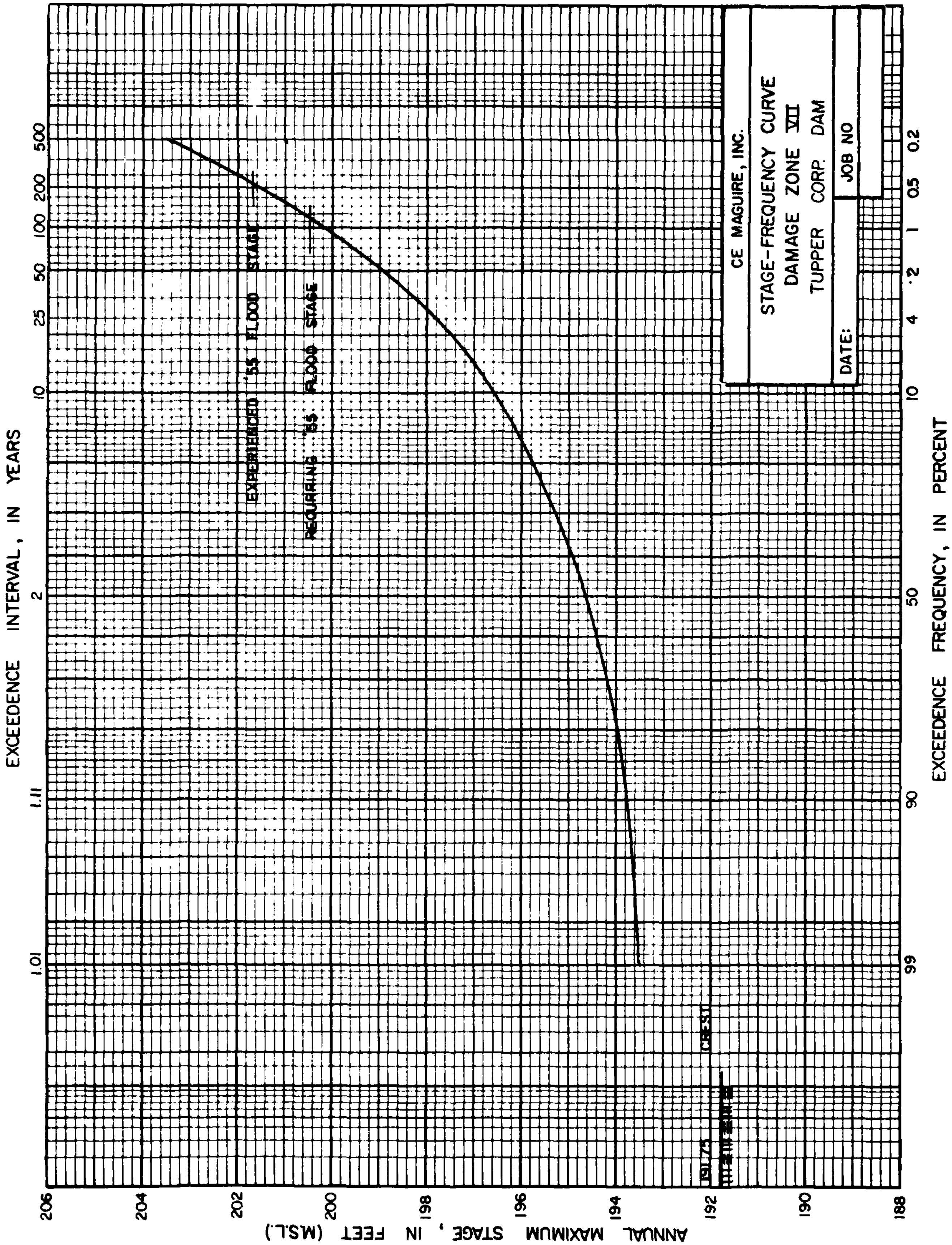

CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE IV
FORMER HAYWARD-SCHUSTER DAM
DATE:
JOB NO
EXCEEDENCE INTERVAL, IN YEARS
500
200
100
50
25
10
2
1.11
1.01
EXCEEDENCE FREQUENCY, IN PERCENT
0.2
0.5
1
2
4
10
50
90
99
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L.)
369
367
365
363
361
359
357
355
353
351
RECURRING '55 FLOOD STAGE
EXPERIENCED '55 FLOOD STAGE
RIVER BOTTOM
351.0

PLATE 39


EXCEEDENCE INTERVAL, IN YEARS
1.01
1.11
2
10
25
50
100
200
500
320
318
316
314
312
310
308
306
304
302
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L.)
RECURRING '55 FLOOD STAGE
EXPERIENCED '55 FLOOD STAGE
305.0
RIVER BOTTOM
99
90
50
10
4
2
1
0.5
0.2
EXCEEDENCE FREQUENCY, IN PERCENT
CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE V
SAUNDERSVILLE DAM
DATE:
JOB NO



EXCEEDENCE INTERVAL, IN YEARS
1.01
1.11
2
10
25
50
100
200
500
285
280
275
270
265
260
255
250
245
240
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L.)
RECURRING '55 FLOOD STAGE
EXPERIENCED '55 FLOOD STAGE
257.0
RIVER BOTTOM
99
90
50
10
4
2
1
0.5
0.2
EXCEEDENCE FREQUENCY, IN PERCENT
CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE VI
DISMANTLED PAUL WHITIN DAM
DATE:
JOB NO



CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE VII
TUPPER CORP. DAM
DATE:
JOB NO
EXCEEDENCE INTERVAL, IN YEARS
1.01
1.11
2
10
25
50
100
200
500
EXCEEDENCE FREQUENCY, IN PERCENT
99
90
50
10
4
2
1
0.5
0.2
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L.)
188
190
192
194
196
198
200
202
204
206
EXPERIENCED '55 FLOOD STAGE
RECURRING '55 FLOOD STAGE
CREST
191.75

PLATE 42

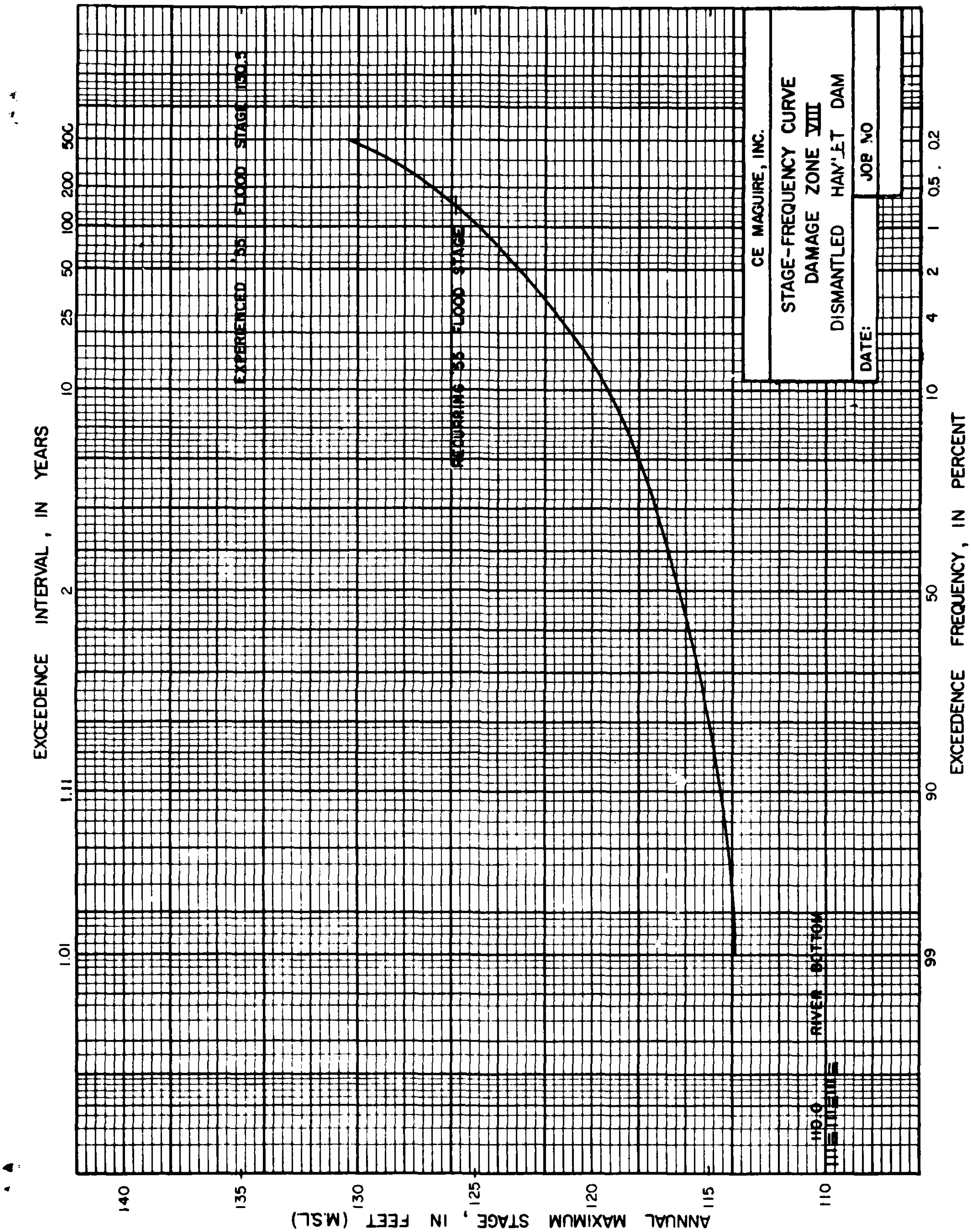
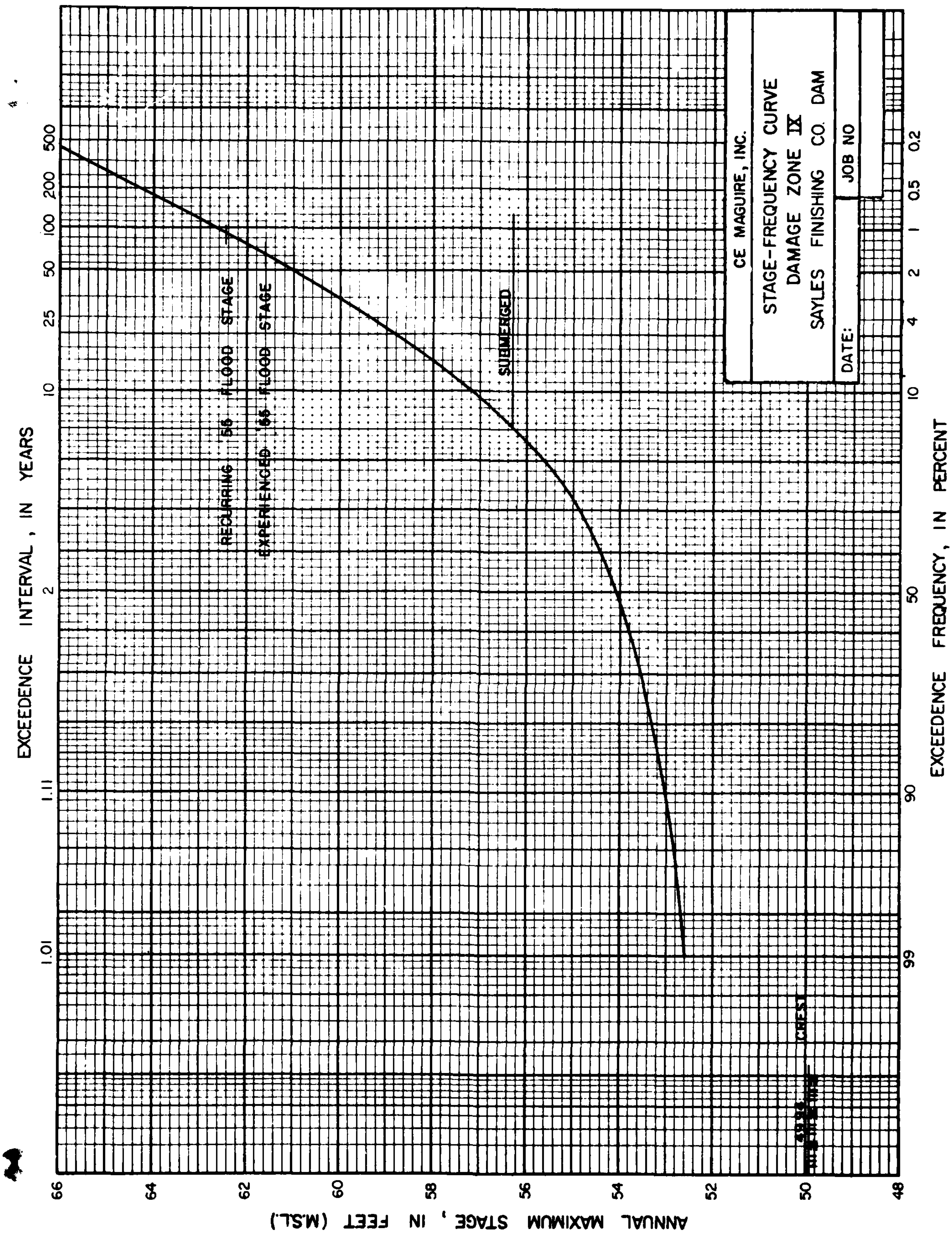

CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE VIII
DISMANTLED HAMLET DAM
DATE:
JOB NO
EXCEEDENCE INTERVAL, IN YEARS
1.01
1.11
2
10
25
50
100
200
500
EXCEEDENCE FREQUENCY, IN PERCENT
99
90
50
10
4
2
1
0.5
0.2
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L)
110
115
120
125
130
135
140
EXPERIENCED '55 FLOOD STAGE 130.3
RECURRING '55 FLOOD STAGE
RIVER BOTTOM
110.0

PLATE 43



CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE IX
SAYLES FINISHING CO. DAM
DATE:
JOB NO
EXCEEDENCE INTERVAL, IN YEARS
1.01
1.11
2
10
25
50
100
200
500
EXCEEDENCE FREQUENCY, IN PERCENT
99
90
50
10
4
2
1
0.5
0.2
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L.)
48
50
52
54
56
58
60
62
64
66
RECURRING '56 FLOOD STAGE
EXPERIENCED '55 FLOOD STAGE
SUBMERGED
CREST

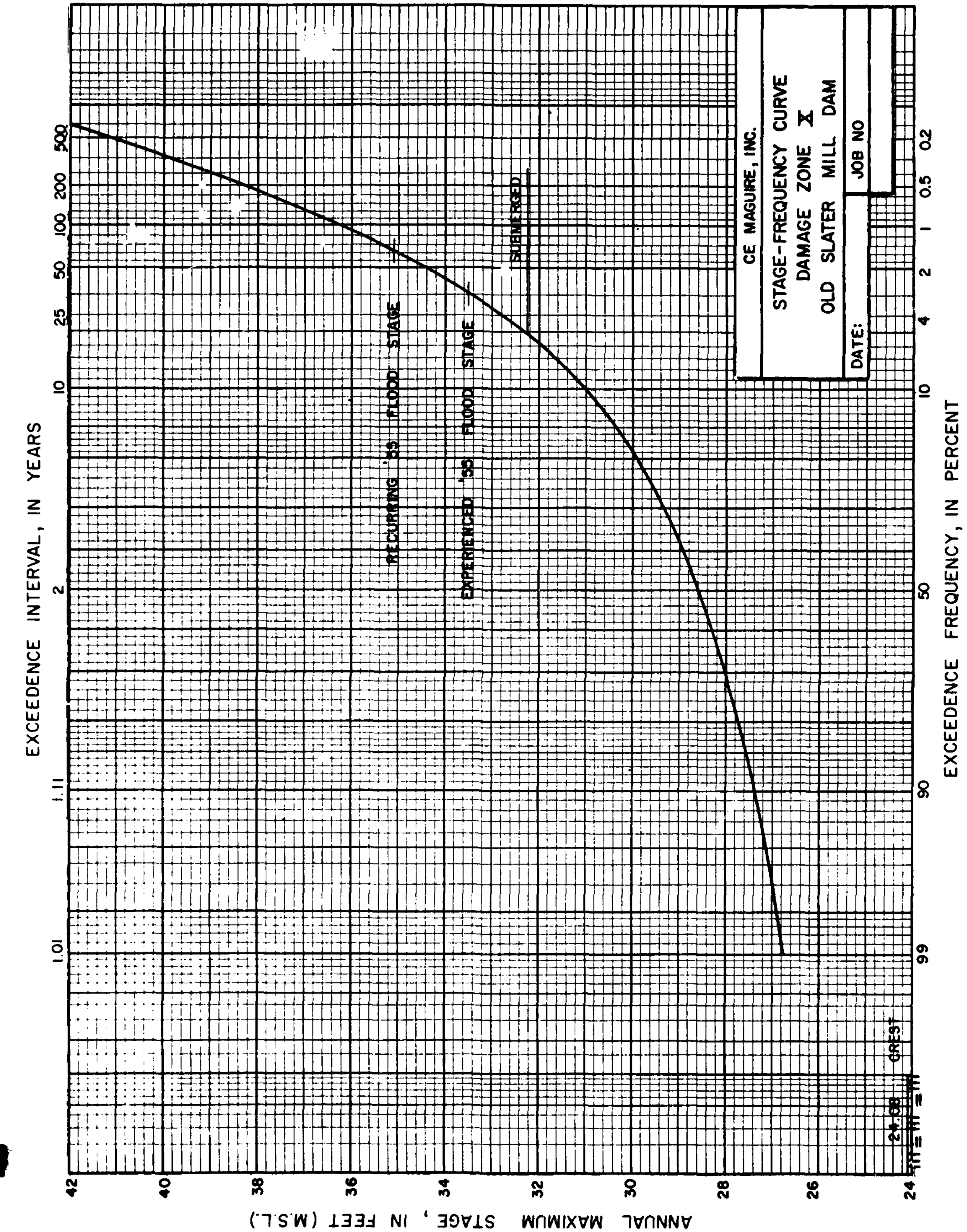
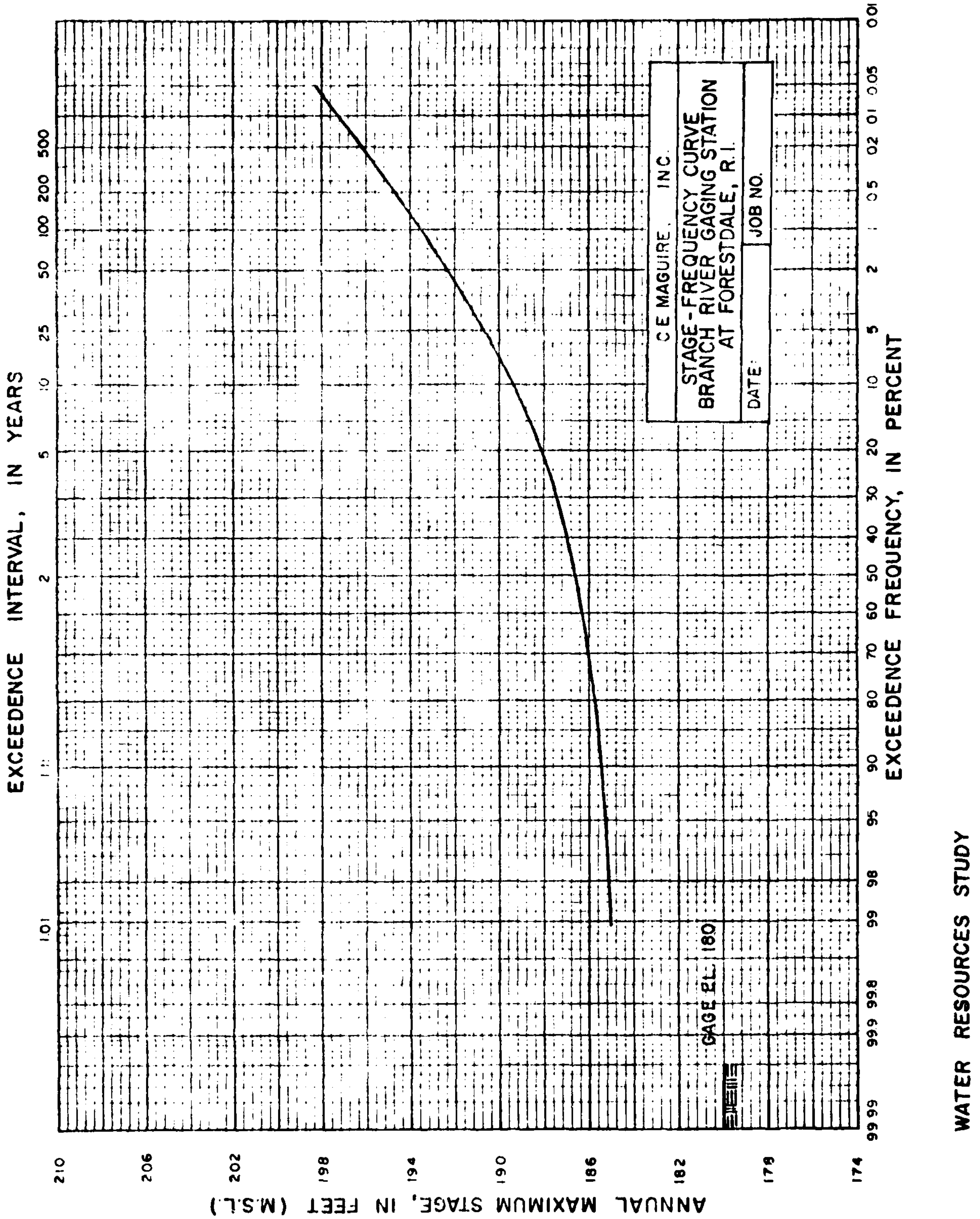
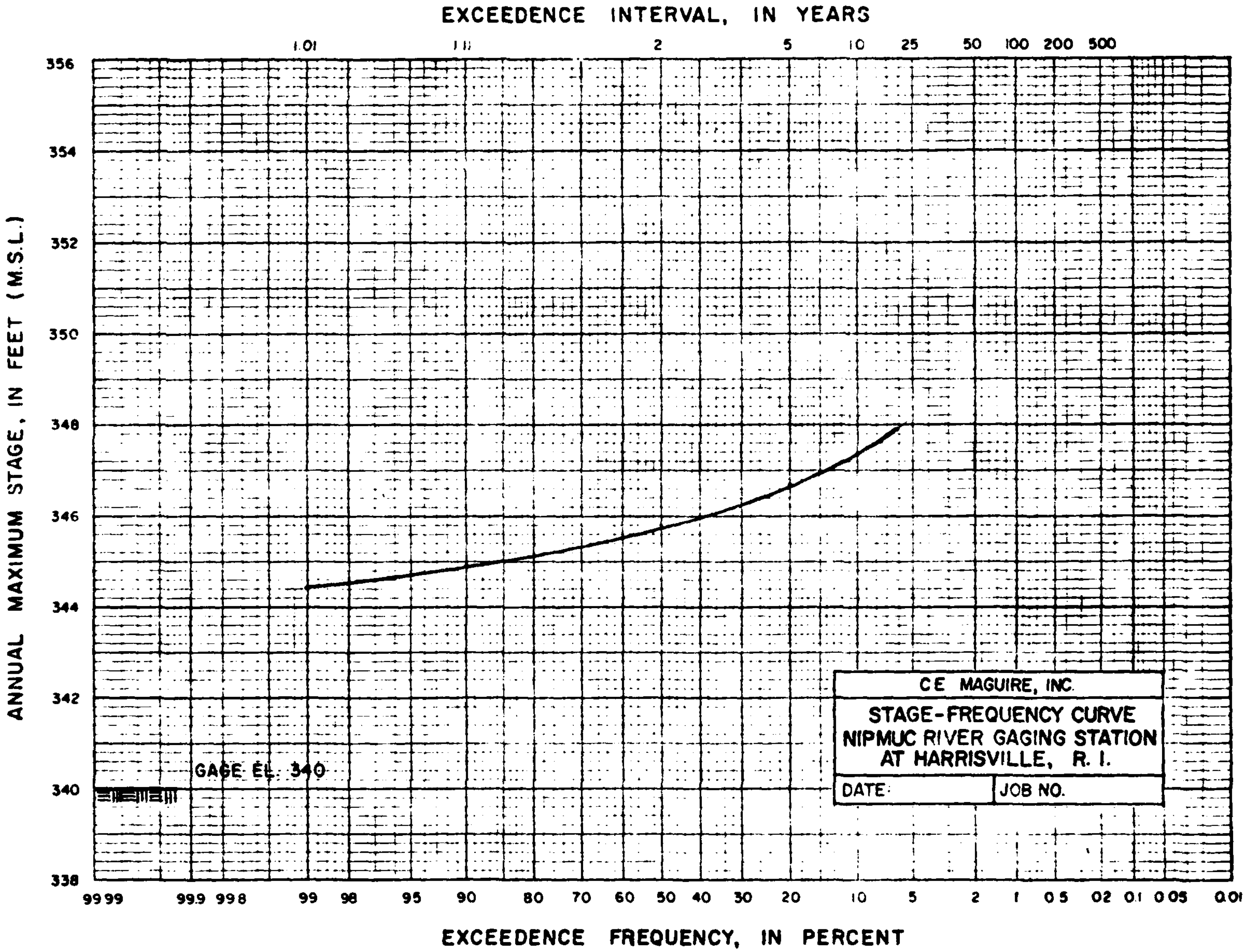
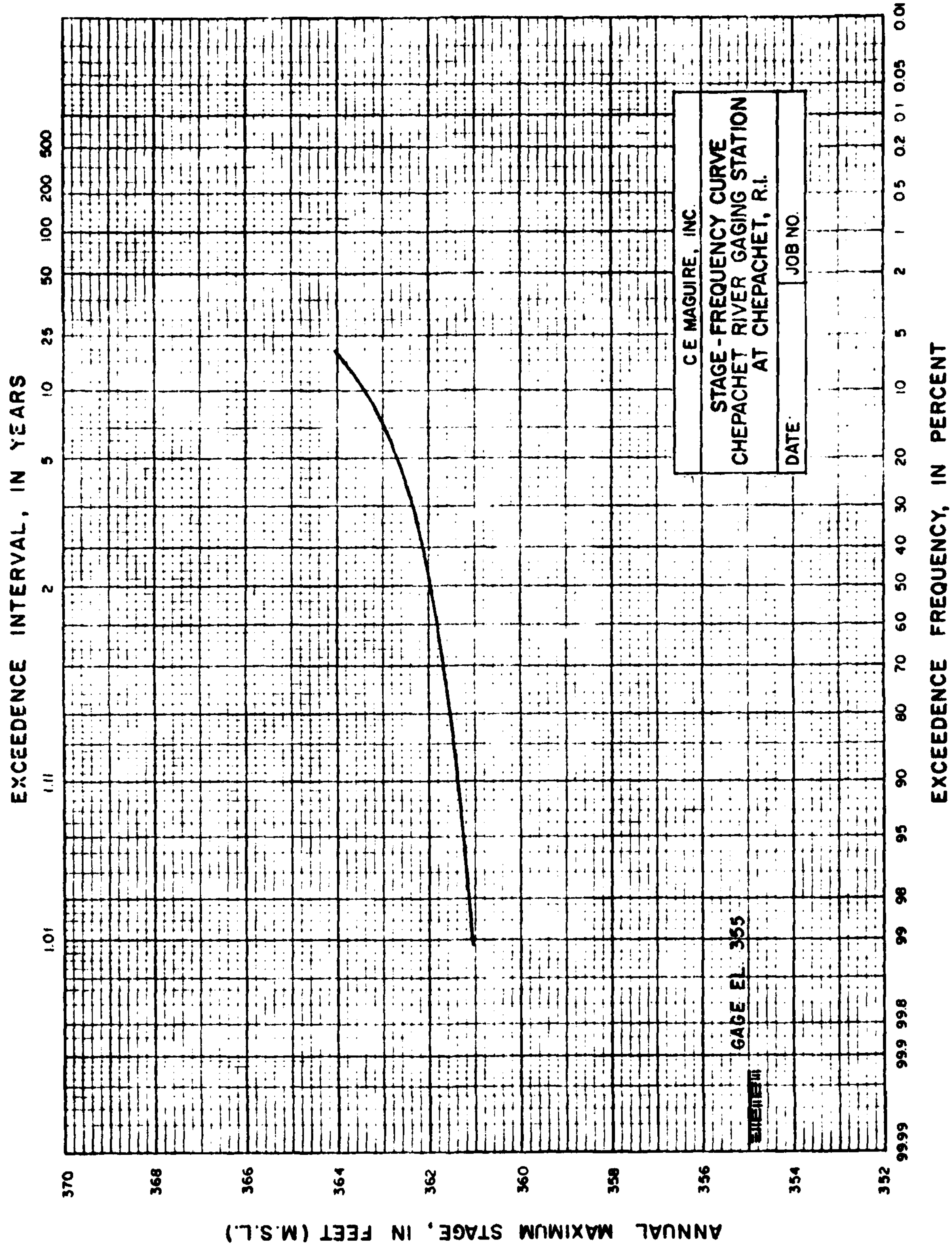

CE MAGUIRE, INC.
STAGE-FREQUENCY CURVE
DAMAGE ZONE X
OLD SLATER MILL DAM
DATE:
JOB NO
EXCEEDENCE INTERVAL, IN YEARS
500
200
100
50
25
10
2
1.11
1.01
EXCEEDENCE FREQUENCY, IN PERCENT
0.2
0.5
1
2
4
10
50
90
99
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L.)
42
40
38
36
34
32
30
28
26
24
RECURRING '55 FLOOD STAGE
EXPERIENCED '55 FLOOD STAGE
SUBMERGED
CREST
24.08

PLATE 45

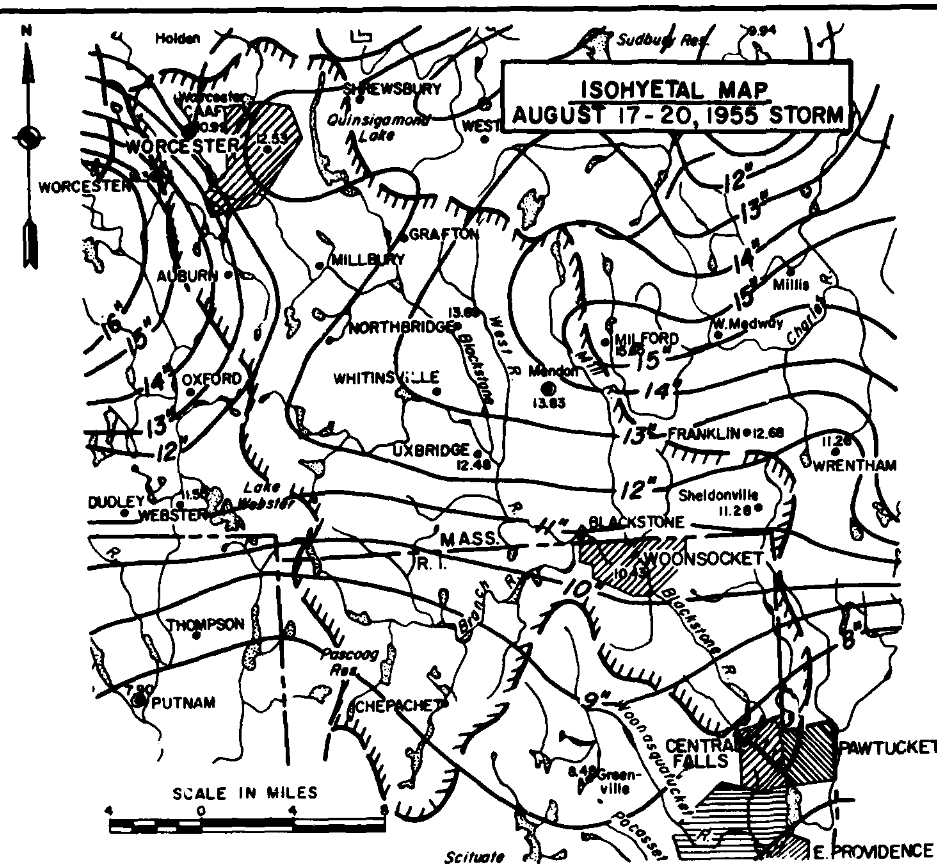

EXCEEDENCE INTERVAL, IN YEARS
1.01
2
5
10
25
50
100
200
500
EXCEEDENCE FREQUENCY, IN PERCENT
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
.5
.2
.1
.05
.01
ANNUAL MAXIMUM STAGE, IN FEET (M.S.L.)
174
178
182
186
190
194
198
202
206
210
GAGE EL. 180
C.E. MAGUIRE, INC.
STAGE-FREQUENCY CURVE
BRANCH RIVER GAGING STATION
AT FORESTDALE, R.I.
DATE:
JOB NO.
WATER RESOURCES STUDY

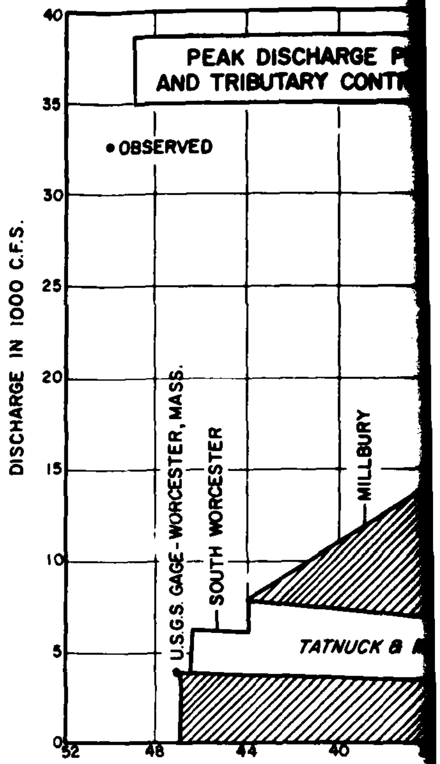


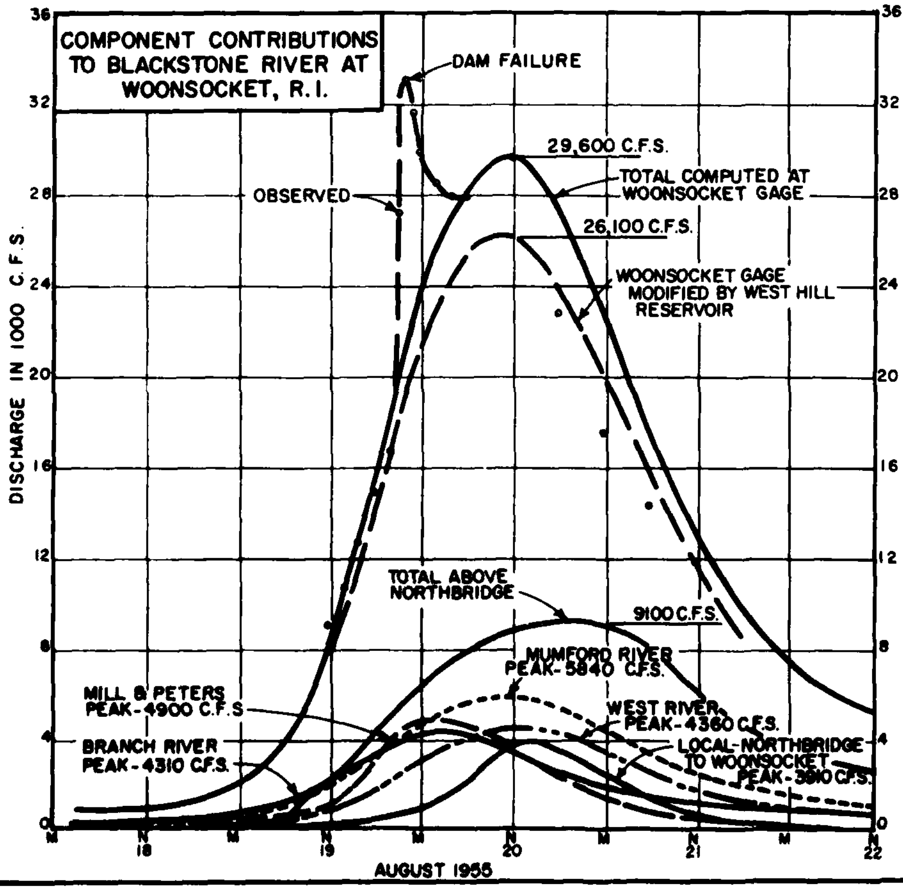
WATER RESOURCES STUDY

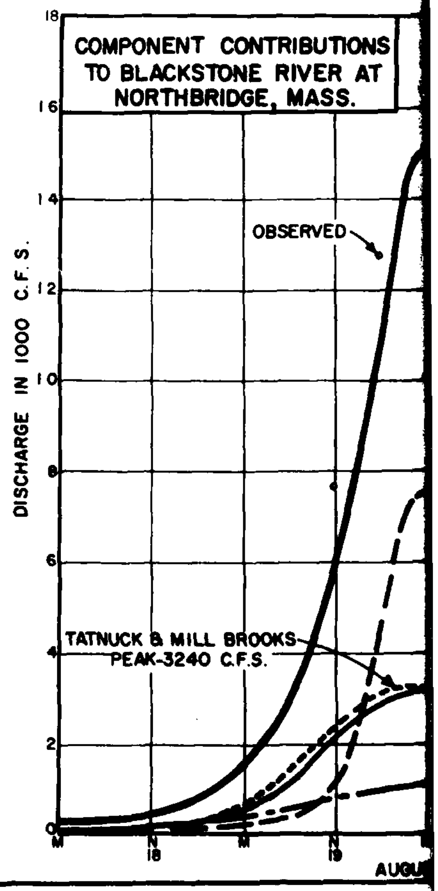


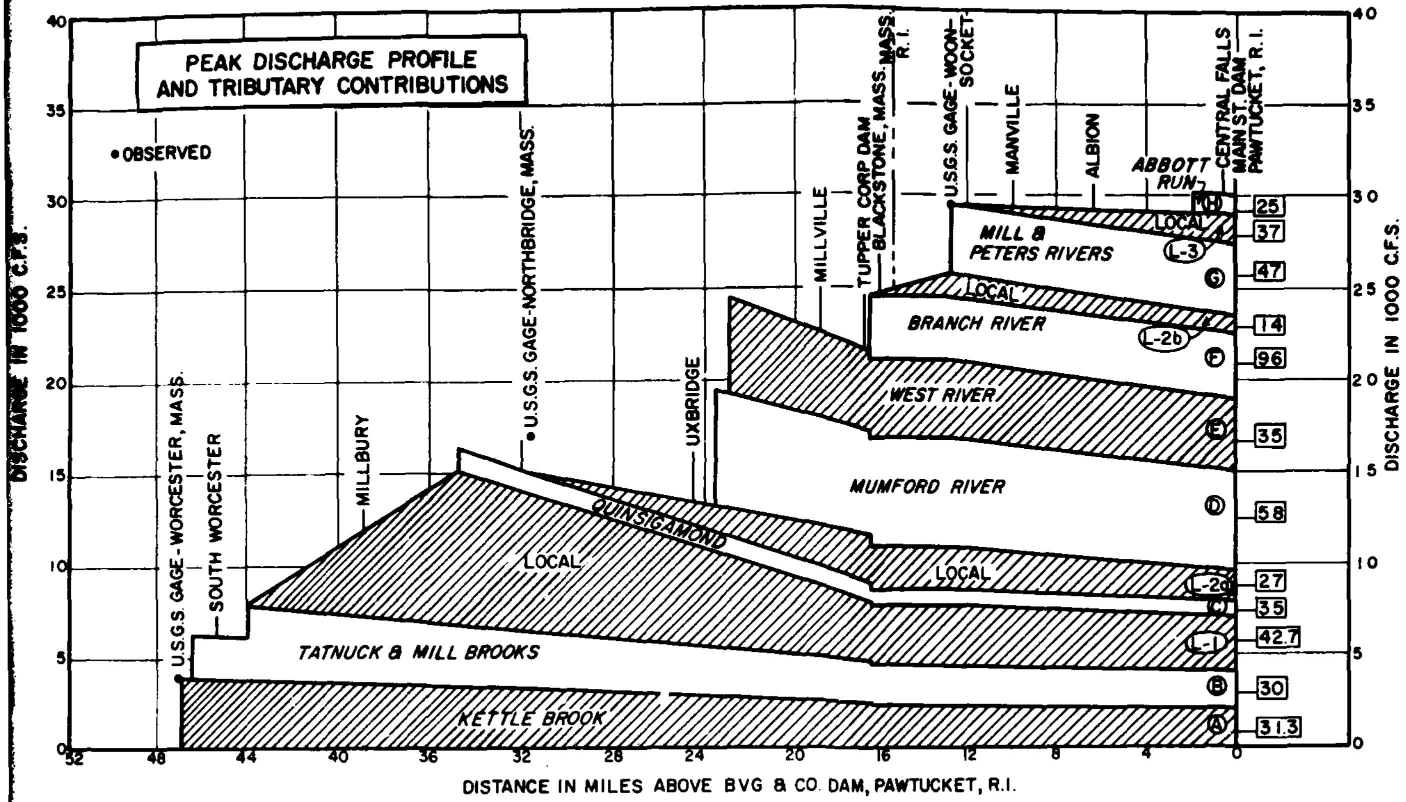
WATER RESOURCES STUDY

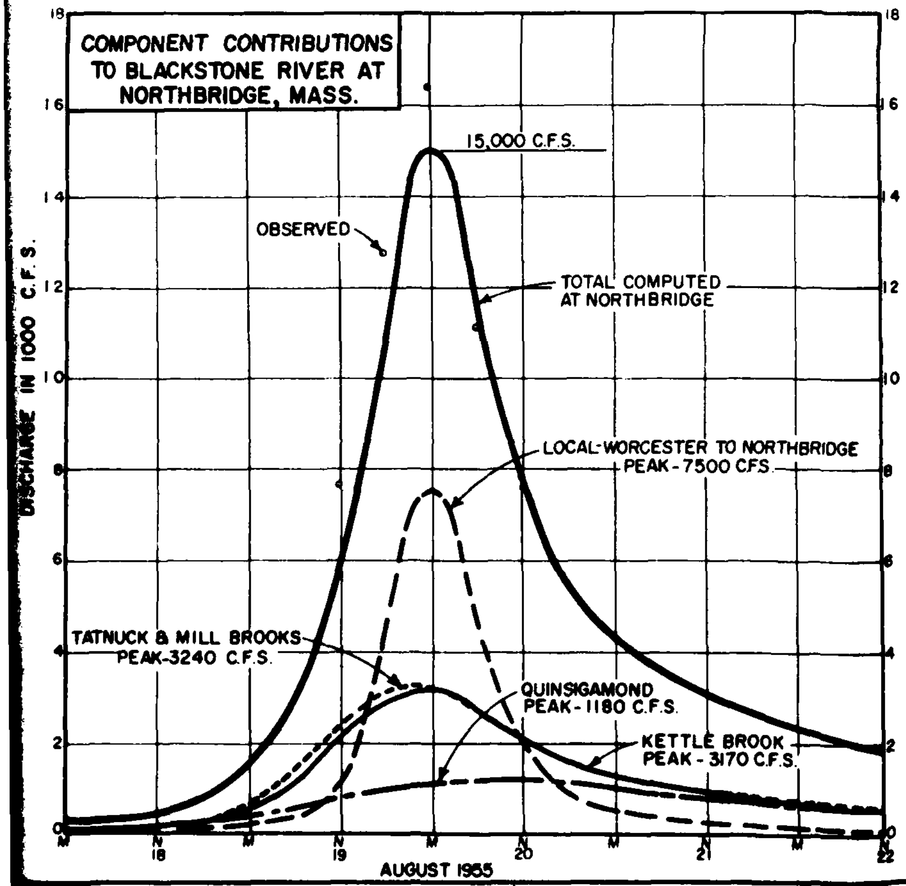

ISOHYETAL MAP
AUGUST 17-20, 1955 STORM
N
Holden
Sudbury Res.
SHREWSBURY
Quinsigamond Lake
WEST
WORCESTER
WORCESTER
AUBURN
GRAFTON
MILLBURY
NORTHBRIDGE
WHITINSVILLE
Blackstone
West R.
Mendon
13.83
MILFORD
W. Medway
Millis
Charles R.
FRANKLIN
12.68
WRENTHAM
OXFORD
UXBRIDGE
12.48
Lake Webster
DUDLEY
WEBSTER
Sheldonville
11.26
BLACKSTONE
MASS.
R.I.
WOONSOCKET
THOMPSON
Branch R.
Pascoag Res.
CHEPACHET
PUTNAM
CENTRAL FALLS
PAWTUCKET
Greenville
Woonasquatucket
Pocasset
Scituate
E. PROVIDENCE
SCALE IN MILES
4 0 4 8
16"
15"
14"
13"
12"
11"
10"
9"
8"


PEAK DISCHARGE P
AND TRIBUTARY CONT
• OBSERVED
DISCHARGE IN 1000 C.F.S.
40
35
30
25
20
15
10
5
0
52
48
44
40
U.S.G.S. GAGE-WORCESTER, MASS.
SOUTH WORCESTER
MILLBURY
TATNUCK &


COMPONENT CONTRIBUTIONS
TO BLACKSTONE RIVER AT
WOONSOCKET, R.I.
DAM FAILURE
29,600 C.F.S.
OBSERVED
TOTAL COMPUTED AT
WOONSOCKET GAGE
26,100 C.F.S.
WOONSOCKET GAGE
MODIFIED BY WEST HILL
RESERVOIR
TOTAL ABOVE
NORTHBRIDGE
9100 C.F.S.
MUMFORD RIVER
PEAK-5840 C.F.S.
MILL & PETERS
PEAK-4900 C.F.S.
WEST RIVER
PEAK-4360 C.F.S.
BRANCH RIVER
PEAK-4310 C.F.S.
LOCAL-NORTHBRIDGE
TO WOONSOCKET
PEAK-3910 C.F.S.
DISCHARGE IN 1000 C.F.S.
36
32
28
24
20
16
12
8
4
0
M
N
18
19
20
21
22
AUGUST 1955


COMPONENT CONTRIBUTIONS
TO BLACKSTONE RIVER AT
NORTHBRIDGE, MASS.
OBSERVED
TATNUCK & MILL BROOKS
PEAK-3240 C.F.S.
DISCHARGE IN 1000 C.F.S.
18
16
14
12
10
8
6
4
2
0
M
N
18
19
AUGU





BLACKSTONE RIVER FLOOD CONTROL

BLACKSTONE RIVER WATERSHED

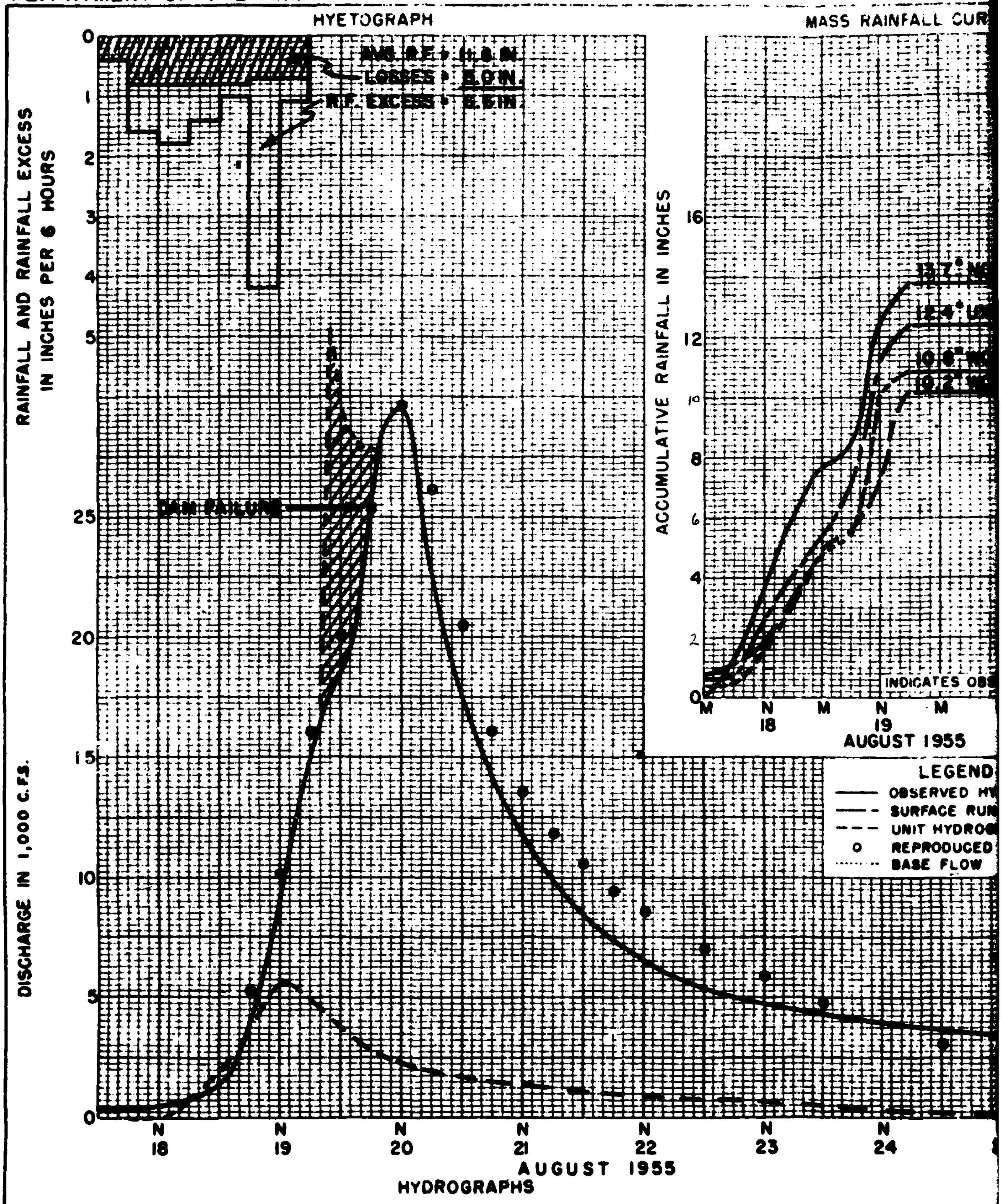
AUGUST 1955 FLOOD

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS

NEW ENGLAND
WALTHAM, MASS.

PLATE 49

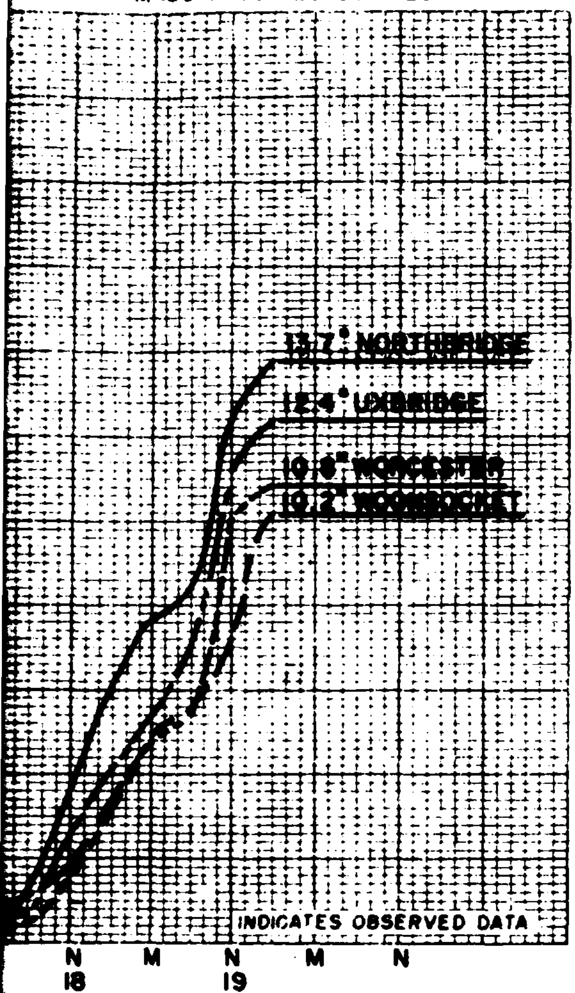
DEPARTMENT OF THE ARMY

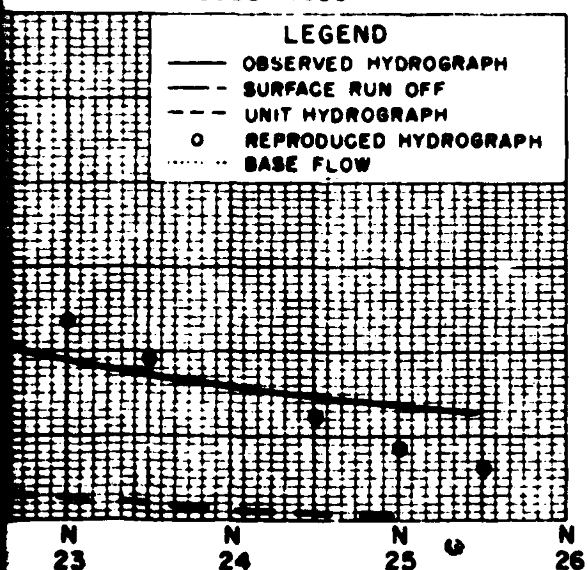


1

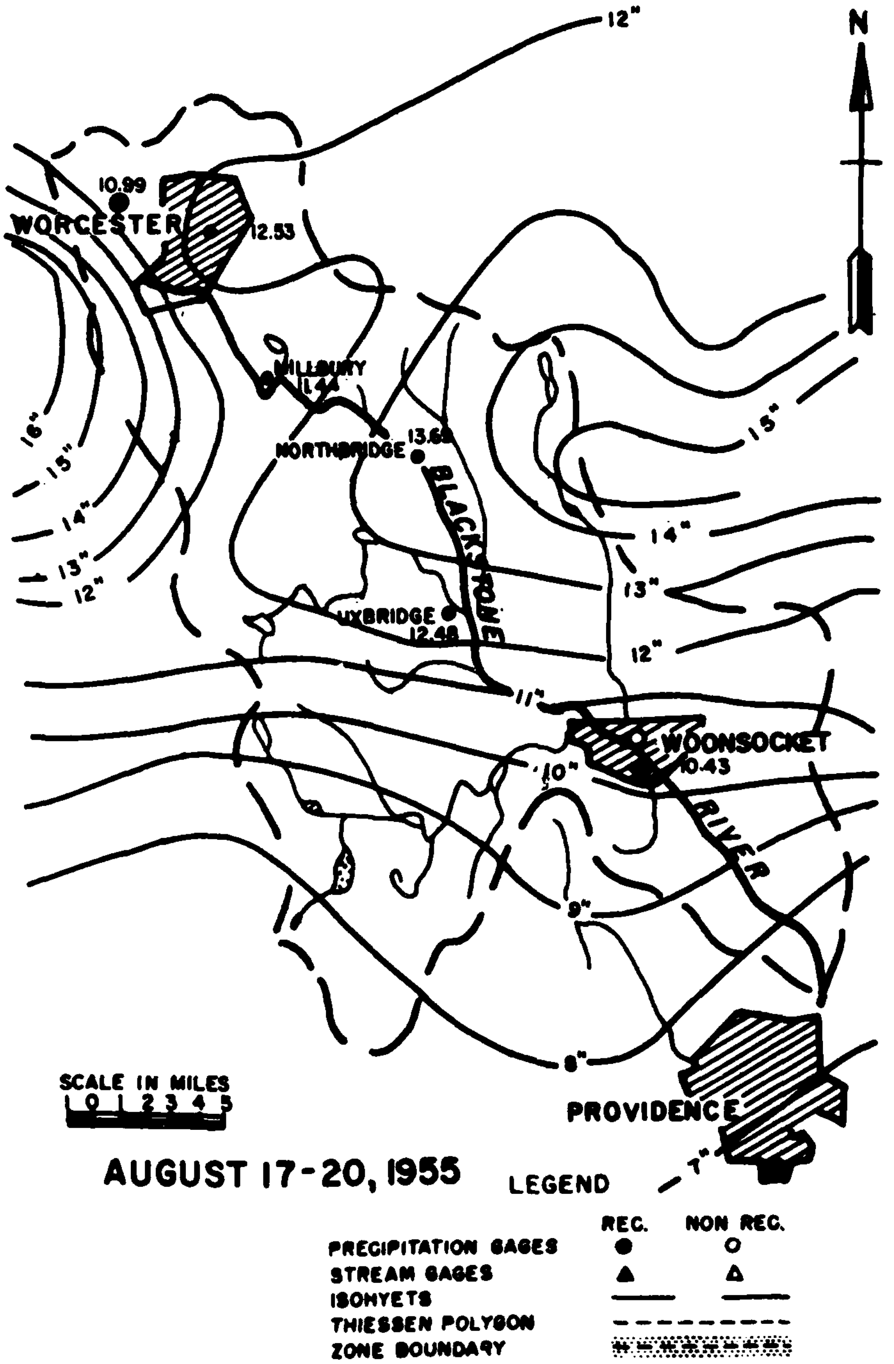
CORPS OF ENGINEERS

MASS RAINFALL CURVES





BASIN MAP



BASIC DATA
(Sheet 1 of 2)

ENGINEERING INVESTIGATIONS
UNIT HYDROGRAPHS

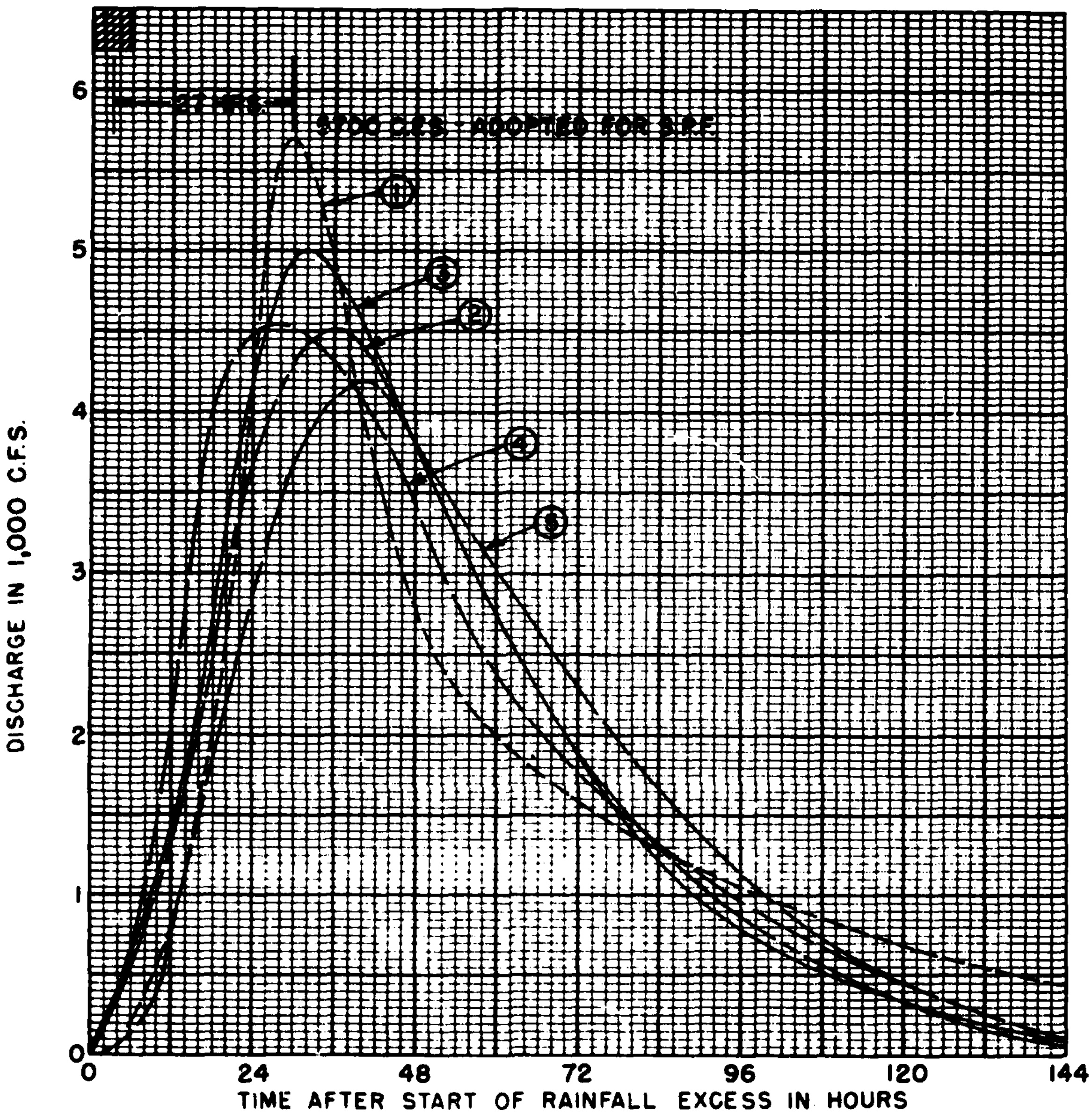
BLACKSTONE RIVER AT WOONSOCKET, R.I.
STORM OF AUGUST 18-19, 1955

SUBMITTED BY
DISTRICT ENGINEER, DISTRICT

1 2

DEPARTMENT OF THE ARMY

OBSERVED UNIT HYDROGRAPHS



DRAINA
MAXIMU
MINIMU
MEAN
LAND S
MAIN S

% DRAINAGE AREA

DATA FROM OBSERVED UNIT HYDROGRAPHS

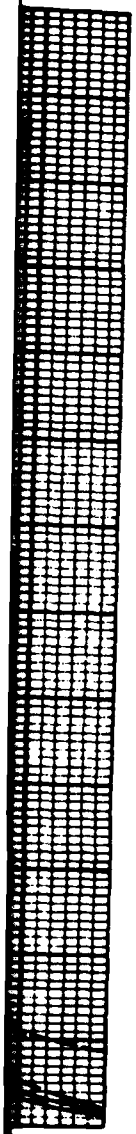
DATE OF RAINFALL	LEGEND	AVE. P (In.)	RAINFALL EXCESS DURATION (hr.)	RAINFALL EXCESS AMOUNT (In.)	L_{cP} (mi.)	STAGE RECORD	Q_{pR} (cfs.)	Q_p tr= hrs. (cfs.)	t_{pR} (hr.)	t_p (hr.)	t (h
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(1
Aug.18-19, 1955	1	11.6	36	6.6	UP	Rec.		5700		27	
Sept.11-12,1954	2	4.9	6	1.9	UN	Rec.		4500		33	
July 23-24,1938	3	3.0	42	2.7	UN	Rec.		5000		30	
Mar.18-19,1936	4	4.6	18	2.7	UP	Rec.		4500		25	
June 8-10,1931	5	5.2	18	1.7	UN	Rec.		4200		36	

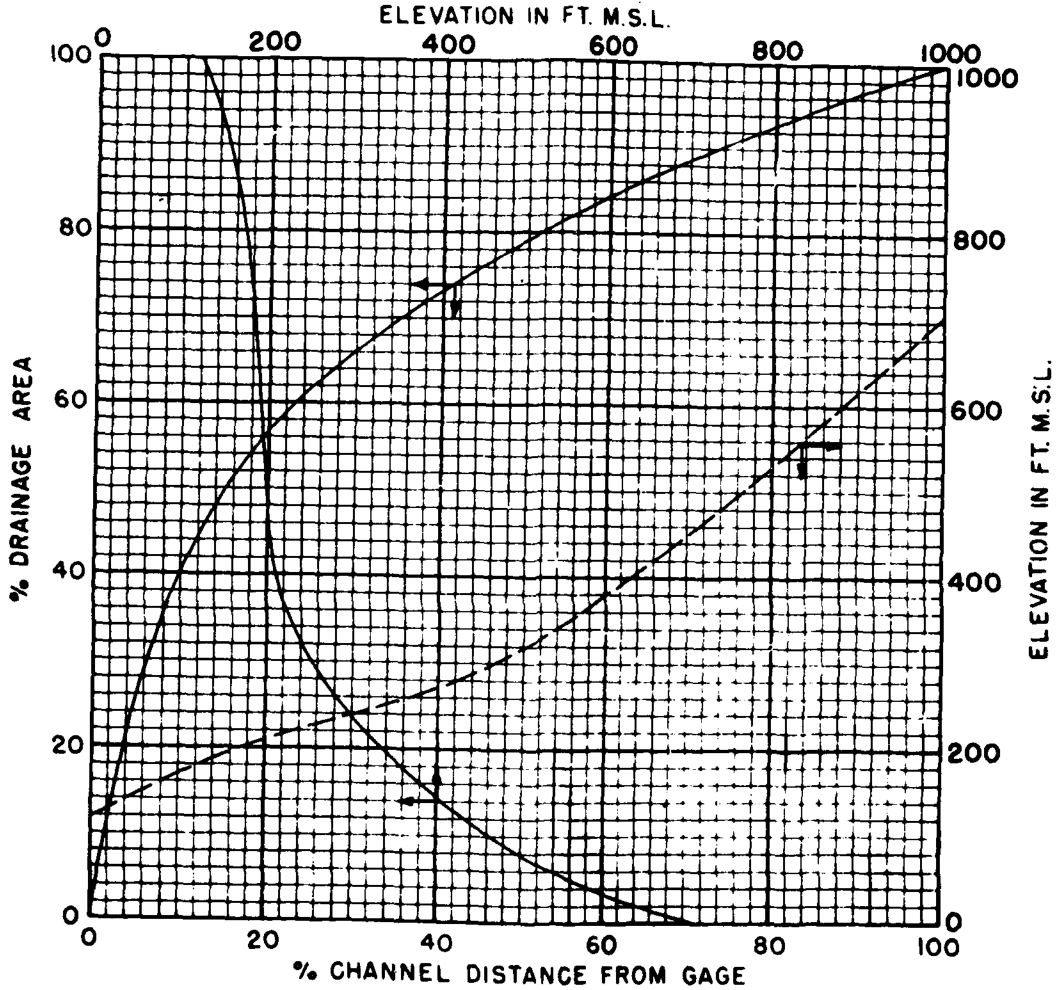
ENG FORM 1 NOV 49 1821

/

DRAINAGE AREA CHARACTERISTICS

DRAINAGE AREA	416 sq. mi.	L	4.5 mi.
MAXIMUM ELEVATION	700 ft. m.s.l.	L_{ca}	16.5 mi.
MINIMUM ELEVATION	120 ft. m.s.l.	$(L L_{ca})^{0.3}$	7.27
MEAN ELEVATION (weighted)	ft. m.s.l.	DRAINAGE DENSITY	mi/sq. mi.
LAND SLOPE	ft./mi.	MAP SCALE	
MAIN STREAM SLOPE	ft./mi.	METHOD OF FLOW SEPARATION	
		BASIN SHAPE FACTOR	





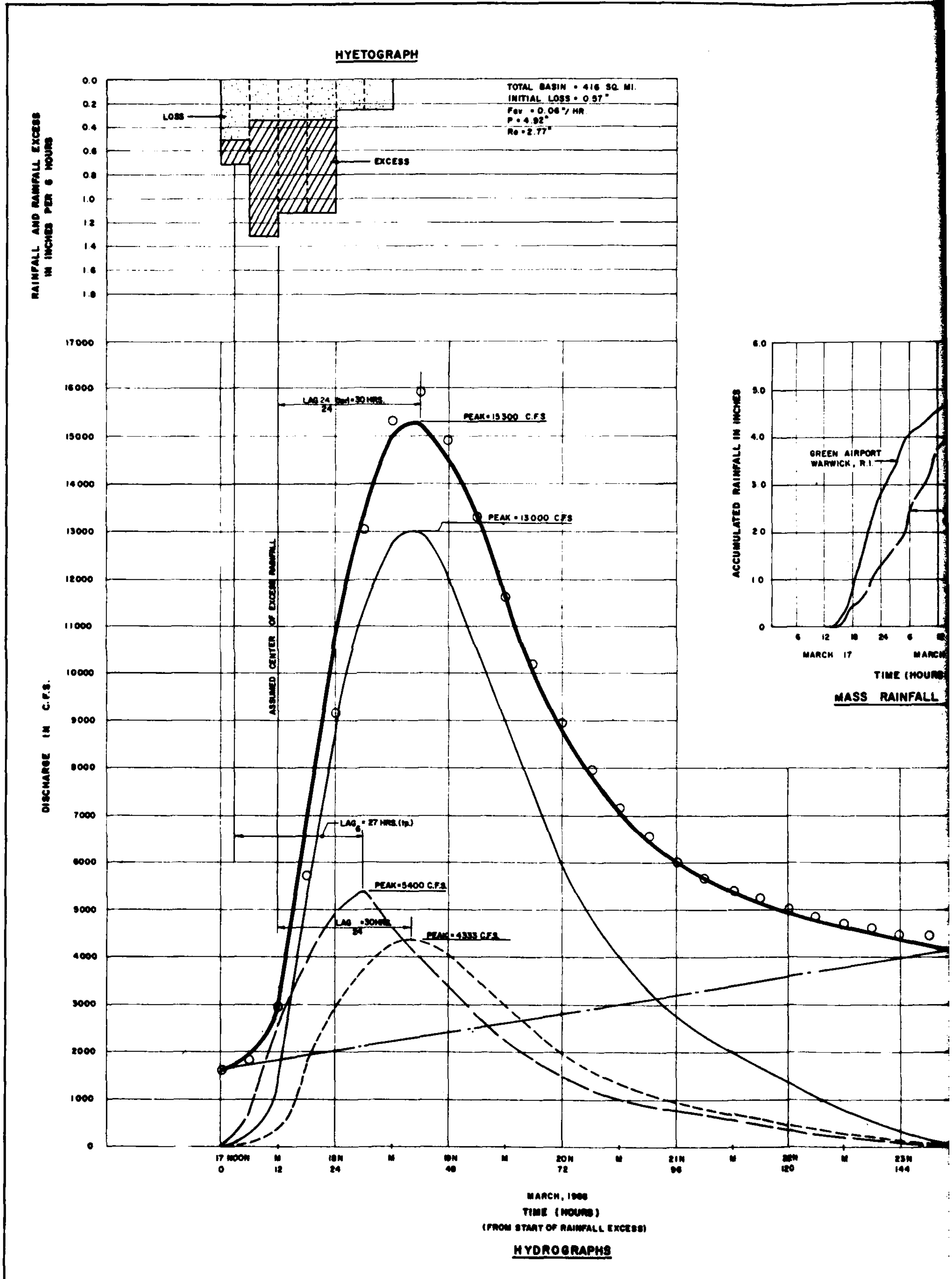
OGRAPHS

Q_p tr = hrs. (cfs.)	t_{pR} (hr.)	t_p (hr.)	t_v (hr.)	C_{tR}	C_p640	K_m (hr.)	T_c (hr.)
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
5700		27		3.7	370		
4500		33		4.5	357		
5000		30		4.1	360		
4500		25		3.4	270		
4200		36		4.9	363		

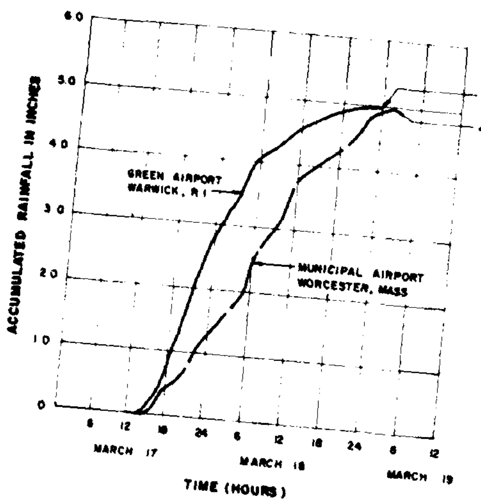
ENGINEERING INVESTIGATIONS
UNIT HYDROGRAPHS

6-HR. UNIT HYDROGRAPHS BLACKSTONE RIVER AT WOONSOCKET, R.I.

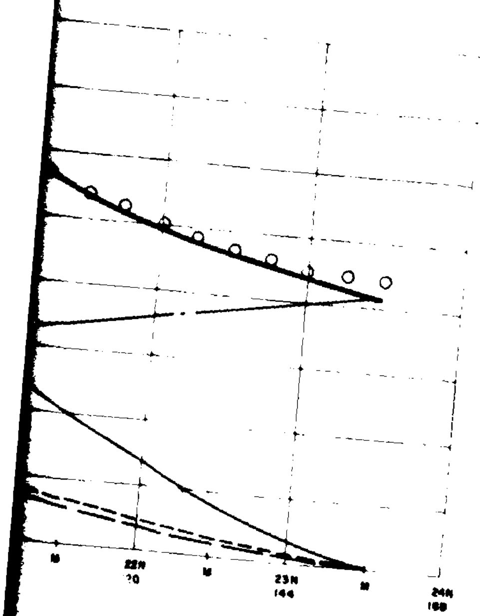
SUBMITTED BY
DISTRICT ENGINEER, DISTRICT.


HYETOGRAPH
TOTAL BASIN = 416 SQ. MI.
INITIAL LOSS = 0.57"
Fav = 0.06"/HR.
P = 4.92"
Re = 2.77"
LOSS
EXCESS
RAINFALL AND RAINFALL EXCESS IN INCHES PER 6 HOURS
DISCHARGE IN C.F.S.
ASSUMED CENTER OF EXCESS RAINFALL
PEAK = 15300 C.F.S.
PEAK = 13000 C.F.S.
PEAK = 5400 C.F.S.
PEAK = 4333 C.F.S.
LAG 6 = 27 HRS. (tp)
MARCH, 1968
TIME (HOURS)
(FROM START OF RAINFALL EXCESS)
HYDROGRAPHS
GREEN AIRPORT WARWICK, R.I.
ACCUMULATED RAINFALL IN INCHES
MARCH 17
TIME (HOURS
MASS RAINFALL

REVISION	DATE	DESCRIPTION	BY

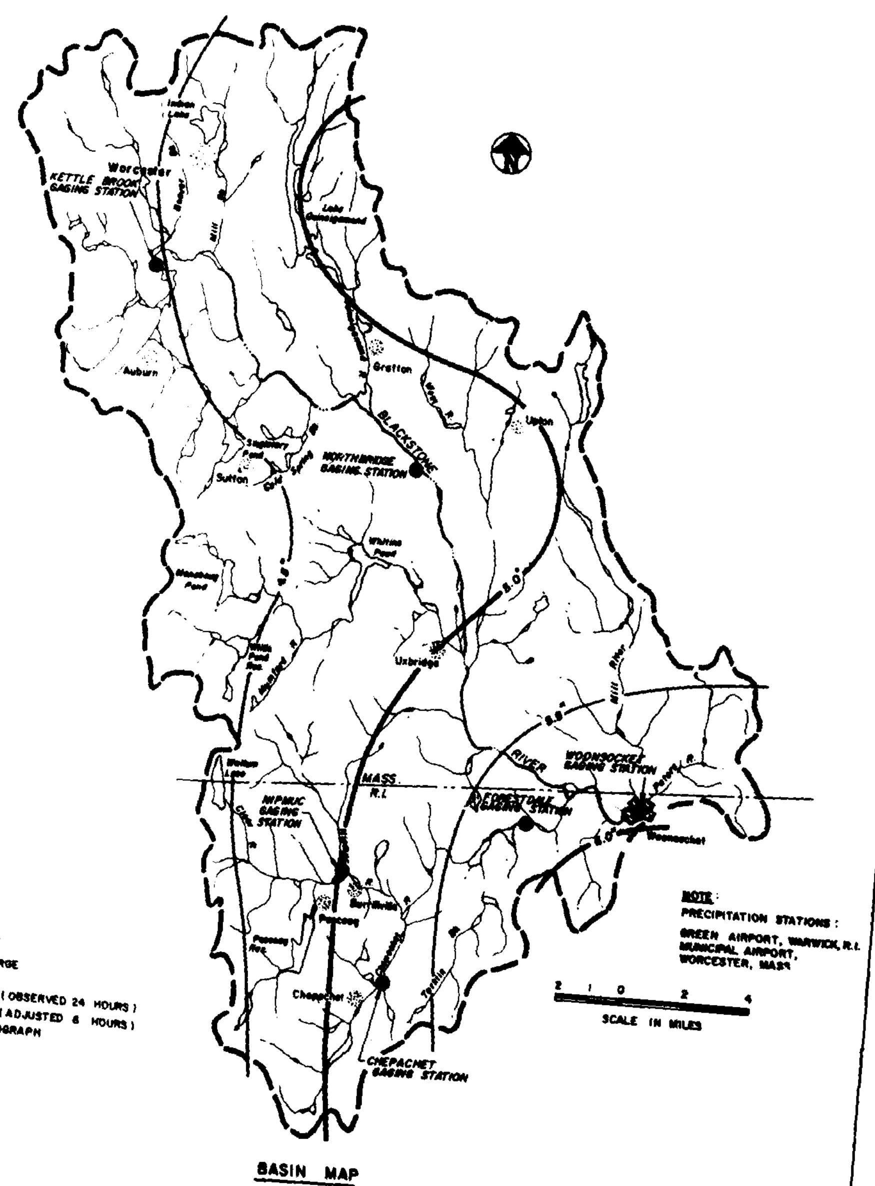


MASS RAINFALL CURVES



LEGEND

OBSERVED DISCHARGE
SURFACE RUN OFF
UNIT HYDROGRAPH (OBSERVED 24 HOURS)
UNIT HYDROGRAPH (ADJUSTED 6 HOURS)
REPRODUCED HYDROGRAPH
BASE FLOW



BASIN MAP

CE MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS
PROVIDENCE, R.I. WALTHAM, MASS. NEW BRITAIN, CONN.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

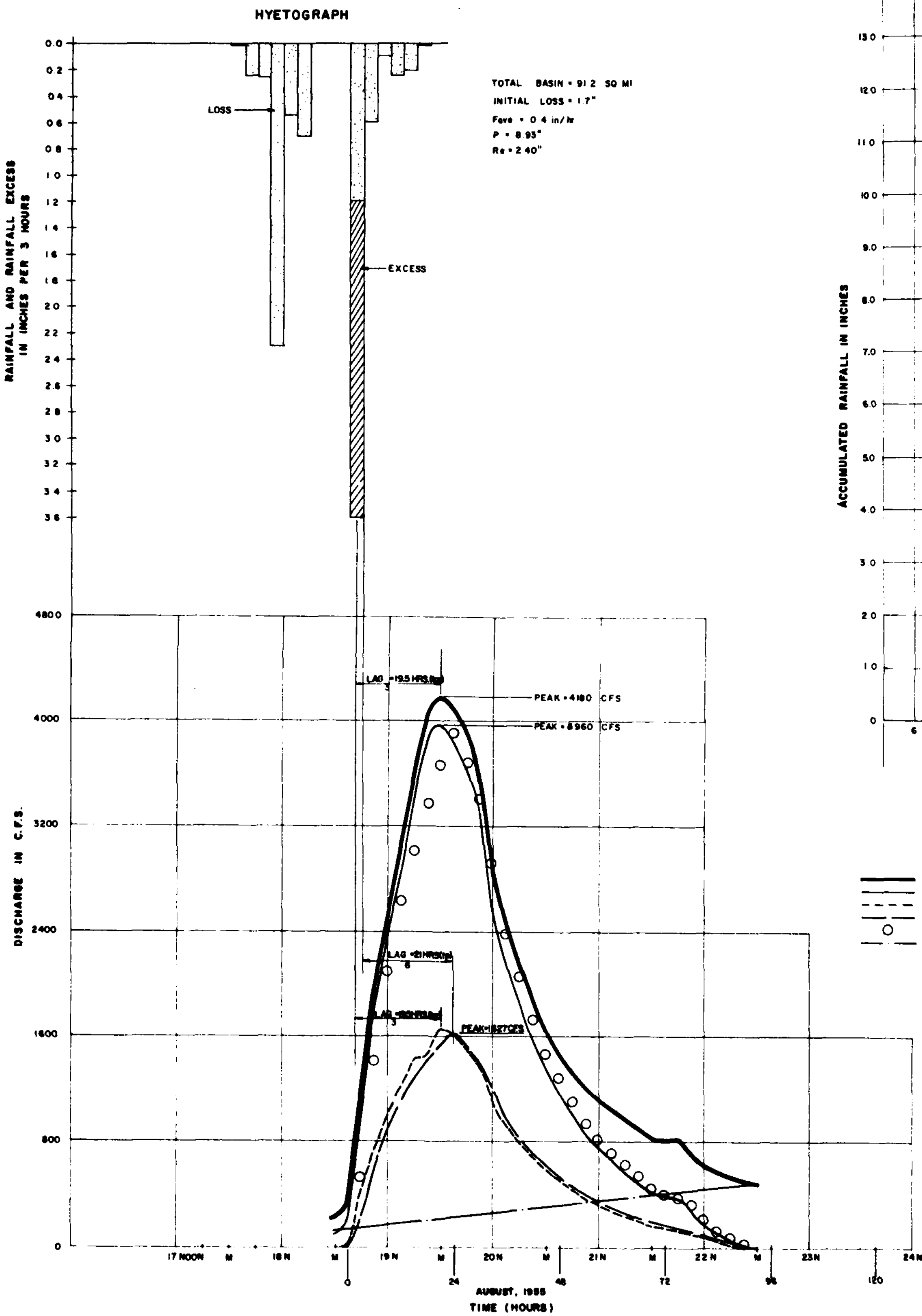
WATER RESOURCES STUDY
UNIT HYDROGRAPHS
BLACKSTONE RIVER AT WOONSOCKET, R.I.
MARCH 17-19, 1968

APPROVED
DATE
SCALE AS SHOWN SPEC. NO.
DRAWING NUMBER
SHEET of

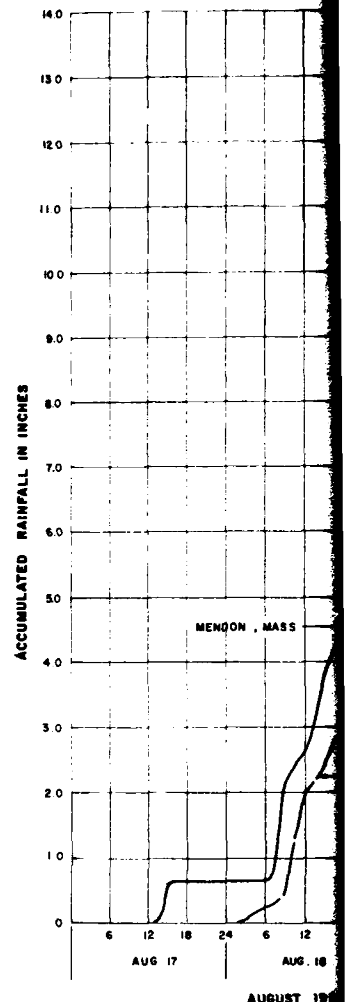
1

2

PLATE 52

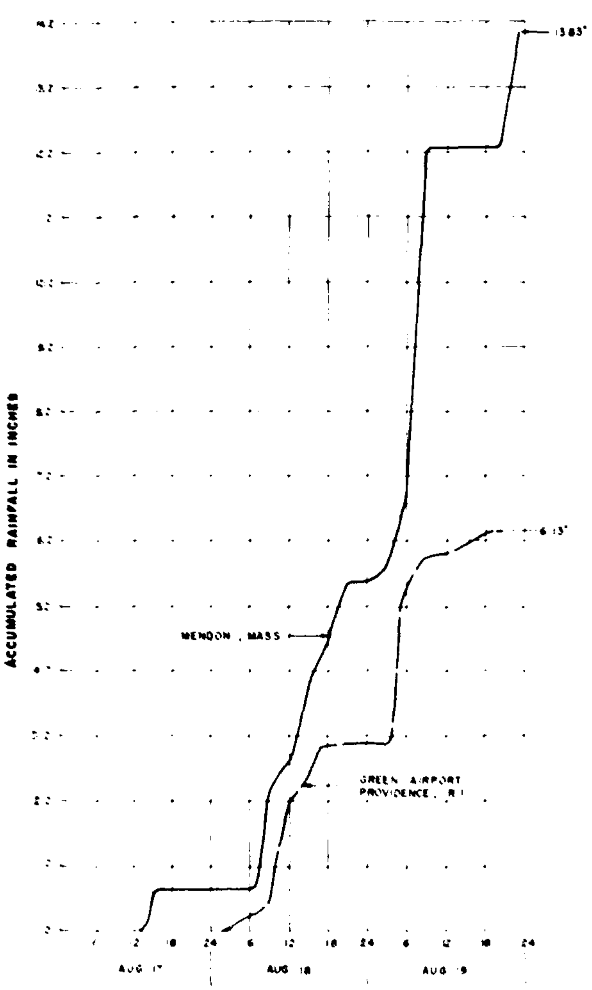


HYDROGRAPHS



MASS RAINFALL

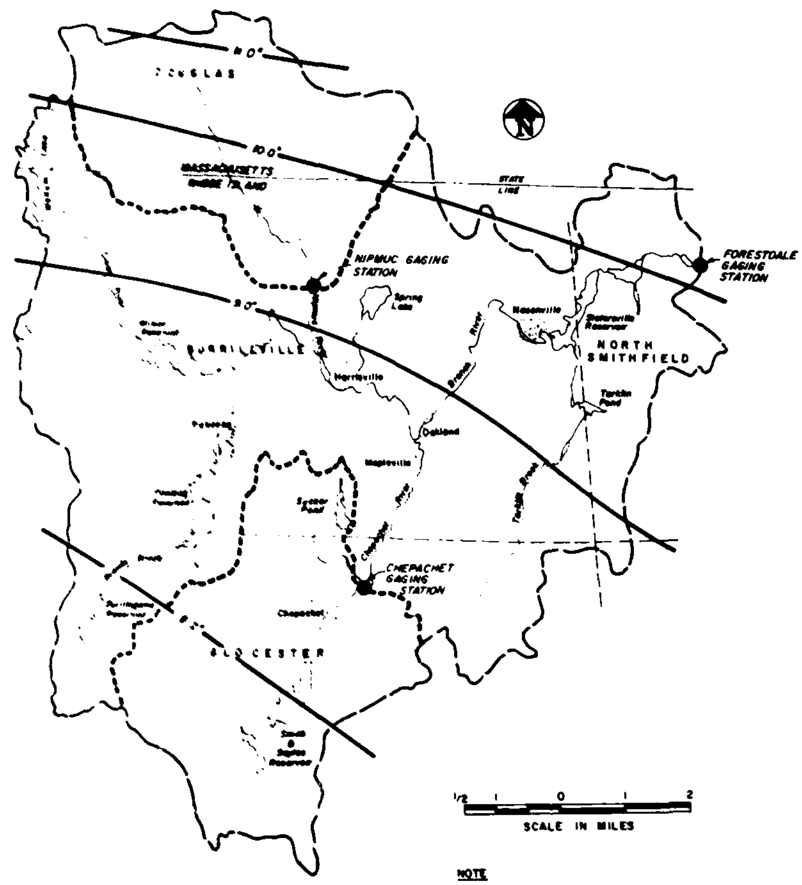
REVISION	DATE	DESCRIPTION	BY



MASS RAINFALL CURVES

LEGEND

- OBSERVED DISCHARGE
- SURFACE RUN OFF
- UNIT HYDROGRAPH (OBSERVED 18 HOURS)
- UNIT HYDROGRAPH (ADJUSTED 6 HOURS)
- REPRODUCED HYDROGRAPH
- BASE FLOW



BASIN MAP

NOTE

PRECIPITATION STATIONS

GREEN AIRPORT WARWICK, R.I.
MENDON, MASS

CE MAGUIRE, INC
ARCHITECTS ENGINEERS PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

DES BY | DR BY | CK BY

WATER RESOURCES STUDY
UNIT HYDROGRAPHS
BRANCH RIVER AT FORESTDALE, RHODE ISLAND
AUGUST 17-19, 1955

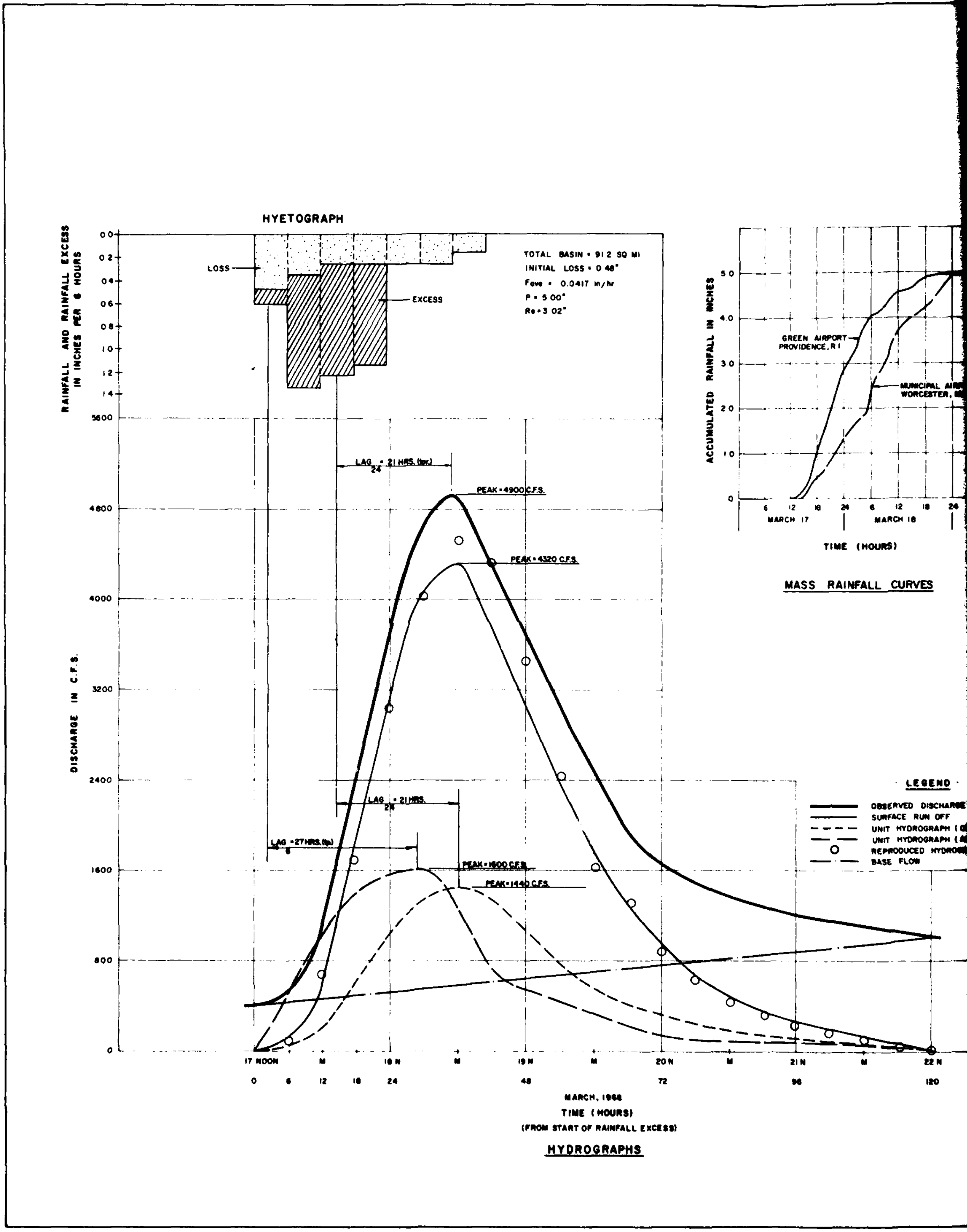
APPROVED | DATE

CHIEF, ENGINEERING DIVISION

SCALE AS SHOWN | SPEC NO.

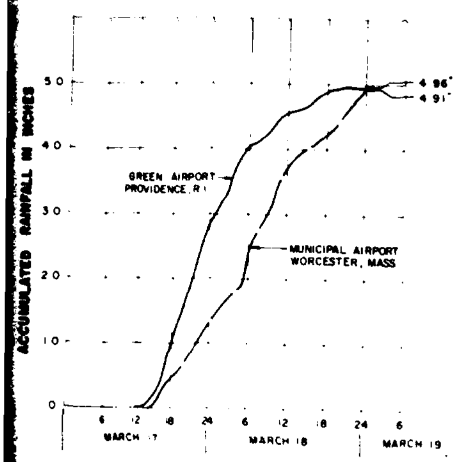
DRAWING NUMBER

SHEET of

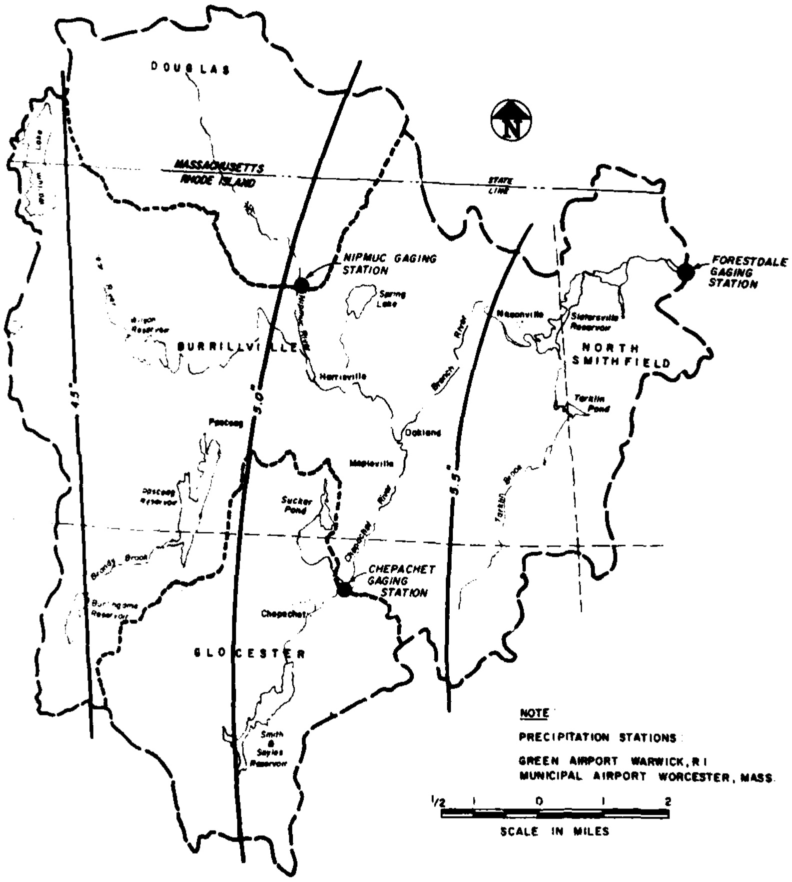


HYETOGRAPH
RAINFALL AND RAINFALL EXCESS IN INCHES PER 6 HOURS
LOSS
EXCESS
TOTAL BASIN = 91.2 SQ MI
INITIAL LOSS = 0.48"
Fave = 0.0417 in/hr
P = 5.00"
Re = 3.02"
DISCHARGE IN C.F.S.
LAG 24 = 21 HRS. (tpr)
PEAK = 4900 C.F.S.
PEAK = 4320 C.F.S.
LAG 24 = 21 HRS.
LAG 6 = 27 HRS. (tp)
PEAK = 1600 C.F.S.
PEAK = 1440 C.F.S.
MARCH, 1968
TIME (HOURS)
(FROM START OF RAINFALL EXCESS)
HYDROGRAPHS
ACCUMULATED RAINFALL IN INCHES
GREEN AIRPORT PROVIDENCE, R.I.
MARCH 17
MARCH 18
TIME (HOURS)
MASS RAINFALL CURVES
LEGEND
OBSERVED DISCHARGE
SURFACE RUN OFF
BASE FLOW

REVISION	DATE	DESCRIPTION	BY



MASS RAINFALL CURVES



NOTE

PRECIPITATION STATIONS

GREEN AIRPORT WARWICK, R.I.
MUNICIPAL AIRPORT WORCESTER, MASS.

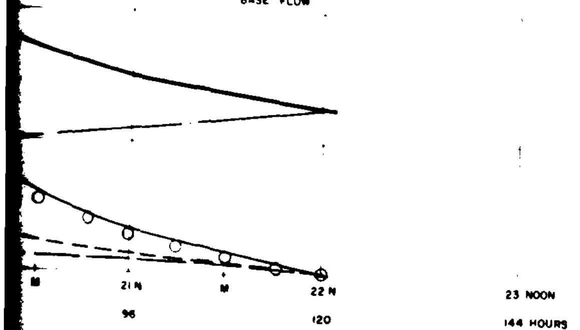
1/2 1 0 1 2

SCALE IN MILES

BASIN MAP

LEGEND

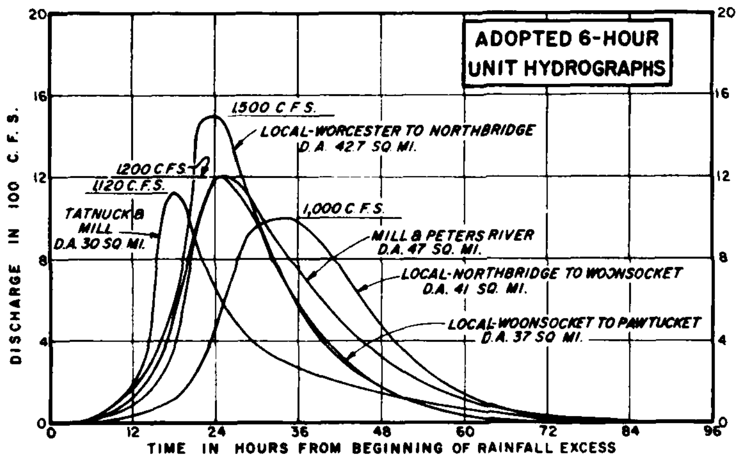
- OBSERVED DISCHARGE
- SURFACE RUN OFF
- UNIT HYDROGRAPH (OBSERVED 24 HOURS)
- UNIT HYDROGRAPH (ADJUSTED 6 HOURS)
- REPRODUCED HYDROGRAPH
- BASE FLOW

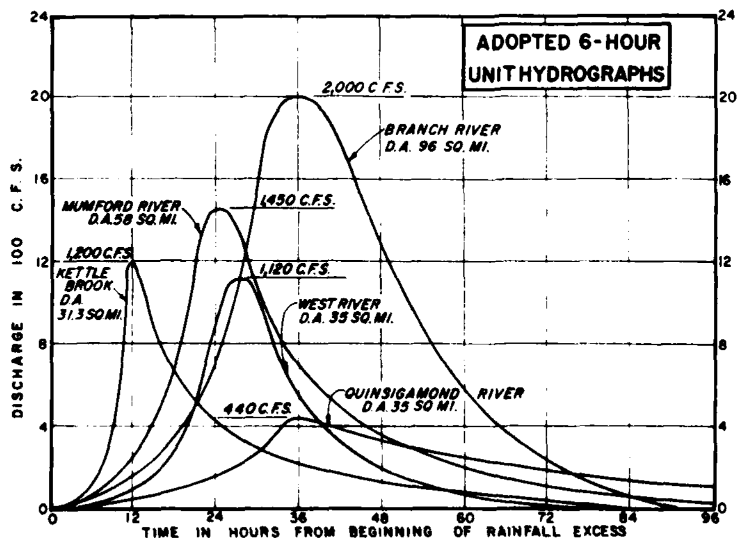


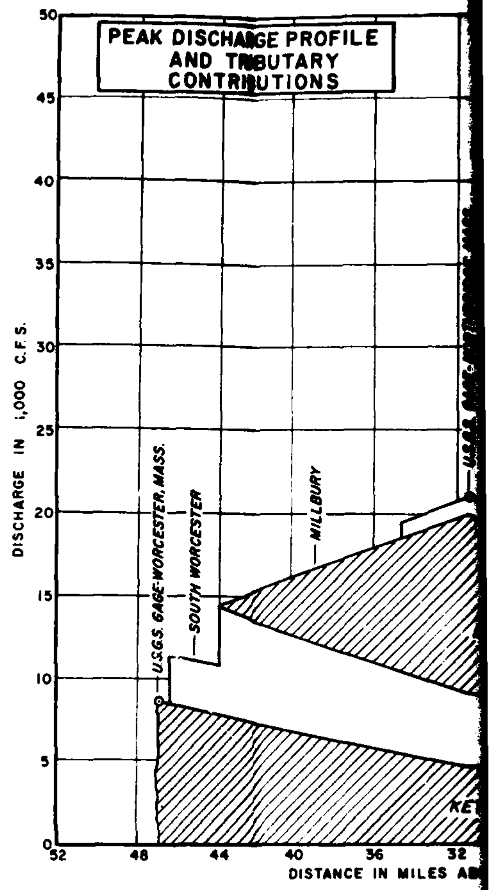
CE MAGUIRE, INC ARCHITECTS ENGINEERS PLANNERS PROVIDENCE, R.I. WALTHAM, MASS. NEW BRITAIN, CONN.	DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.
DES BY / DR BY / CK BY SUBMITTED CHIEF, HYD. ENG. SECTION REVIEWED PROJECT ENGINEER APPROVAL RECOMMENDED CHIEF, COMP. & BASIN SECTION APPROVAL RECOMMENDED CHIEF, PLANN. & RPTS. BRANCH	WATER RESOURCES STUDY **UNIT HYDROGRAPHS** **BRANCH RIVER AT FORESTDALE, RHODE ISLAND** **MARCH 17-19, 1968** APPROVED DATE CHIEF, ENGINEERING DIVISION SCALE AS SHOWN SPEC. NO DRAWING NUMBER SHEET of

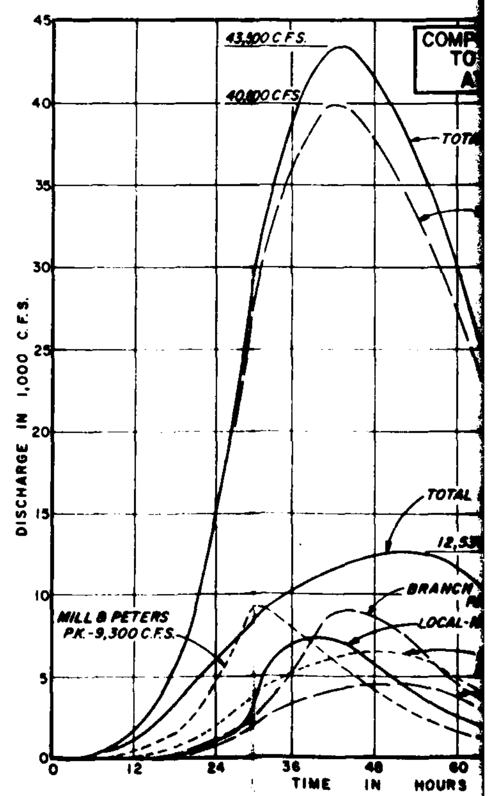
PLATE 54

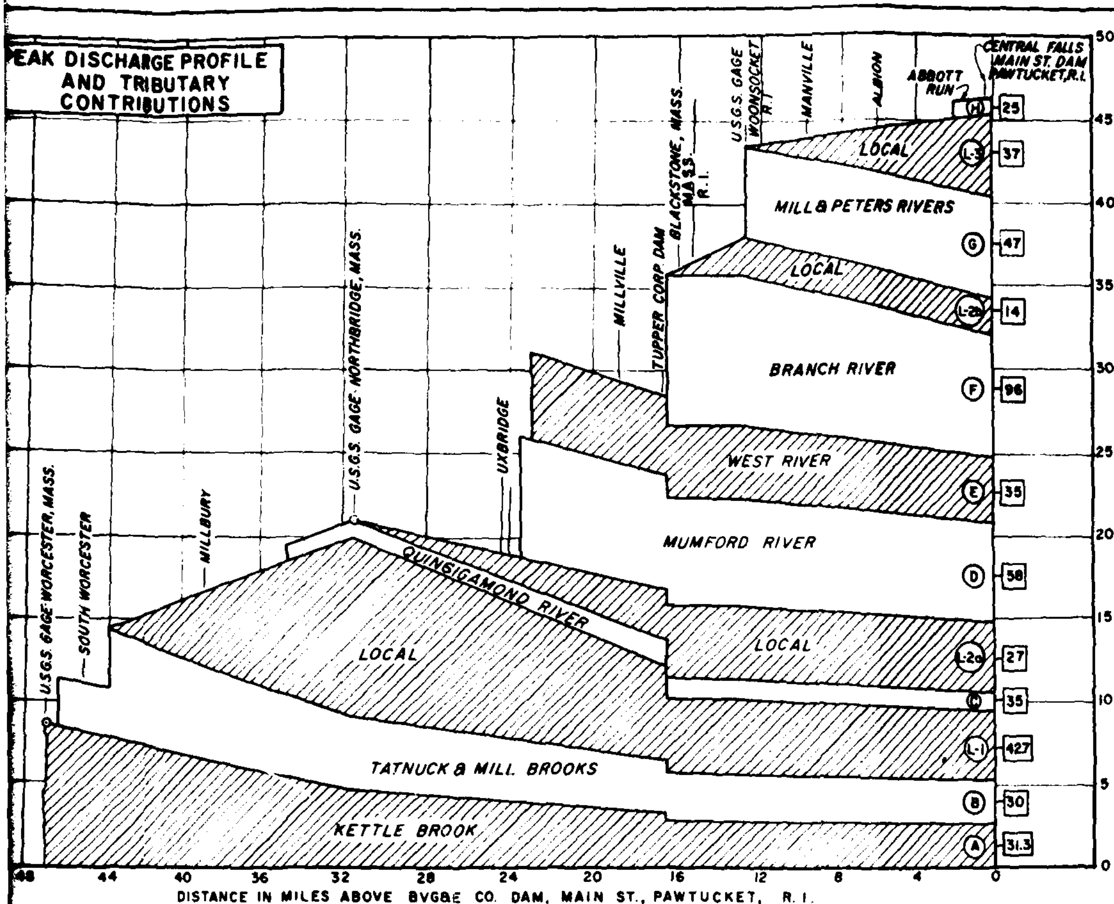
TRIBUTARY	DRAINAGE AREA SQ. MI.	COMPUTED 6-HR.U.H.		ADOPTED 6-HR. U.H.	tp
		MAR.1936	AUG.1955		
KETTLE BROOK	31.3	700	950	1200	9
TATNUCK & MILL RIVERS	30		900	1120	15
LOCAL (L-1)	42.7	1480	1200	1500	21
QUINSIGAMOND RIVER	35		350	440	33
MUMFORD RIVER	58	1100	1200	1450	21
WEST RIVER	35		1000	1120	24
BRANCH RIVER	96	1500	1550	2000	33
LOCAL (L-2a & L-2b)	41		800	1000	30
MILL & PETERS RIVERS	47		760	1200	23
LOCAL (L-3)	37	940	950	1200	21









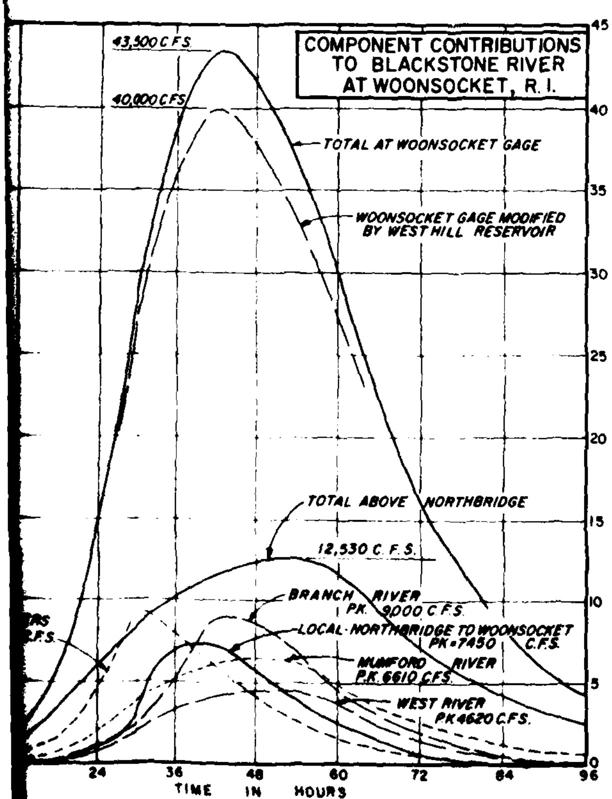


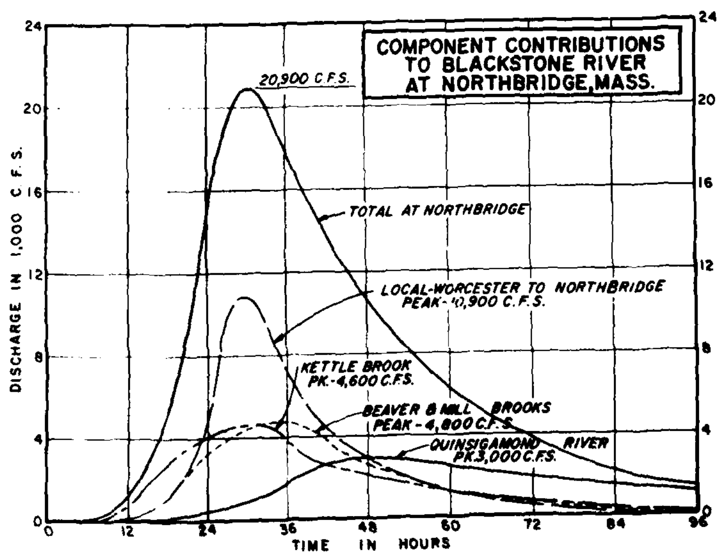
NOTES:

96 Drainage area in sq. mi.

D Areal sub-division

See Plate No. 1





BLACKSTONE RIVER FLOOD CONTROL

BLACKSTONE RIVER WATERSHED

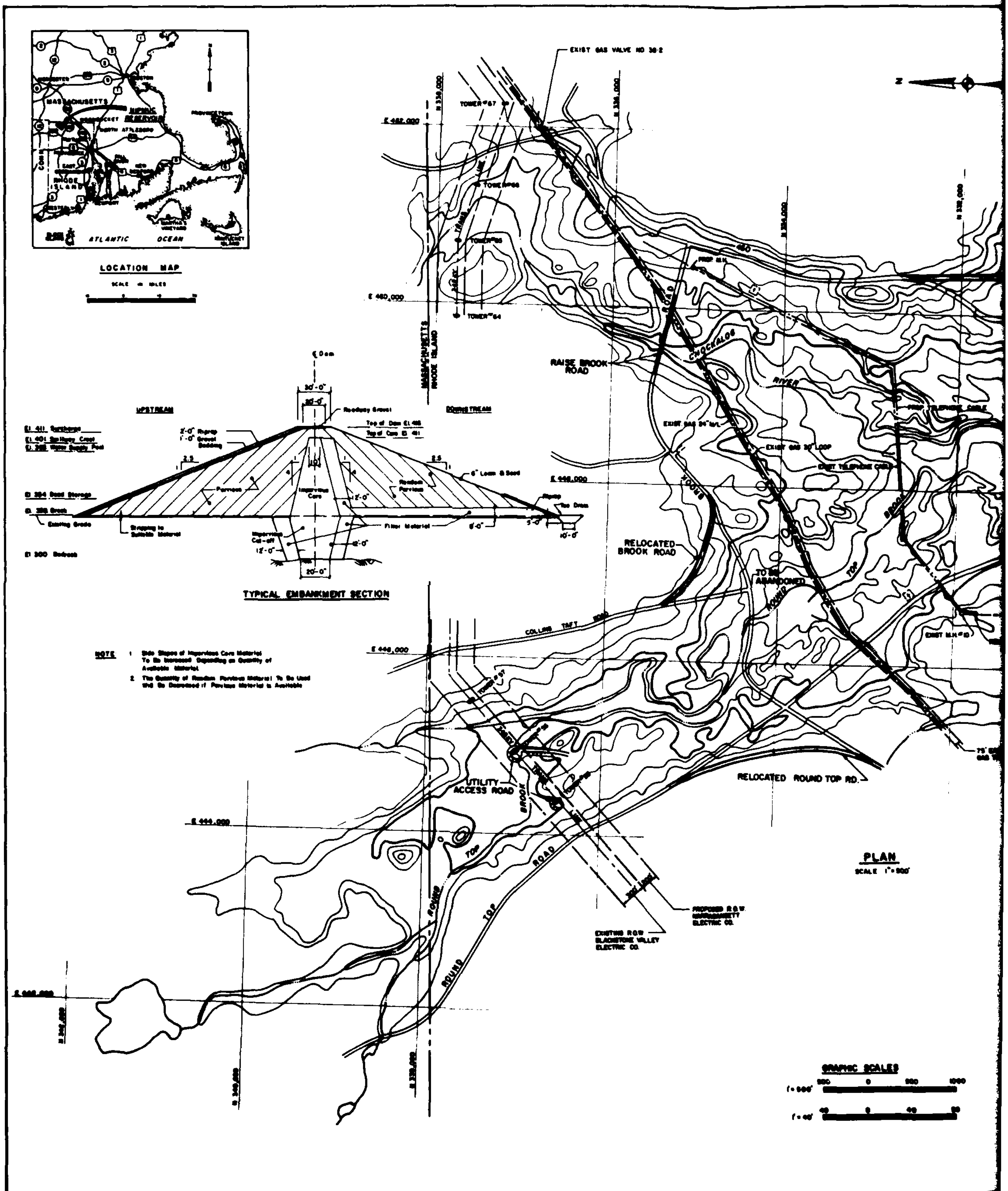
STANDARD PROJECT FLOOD

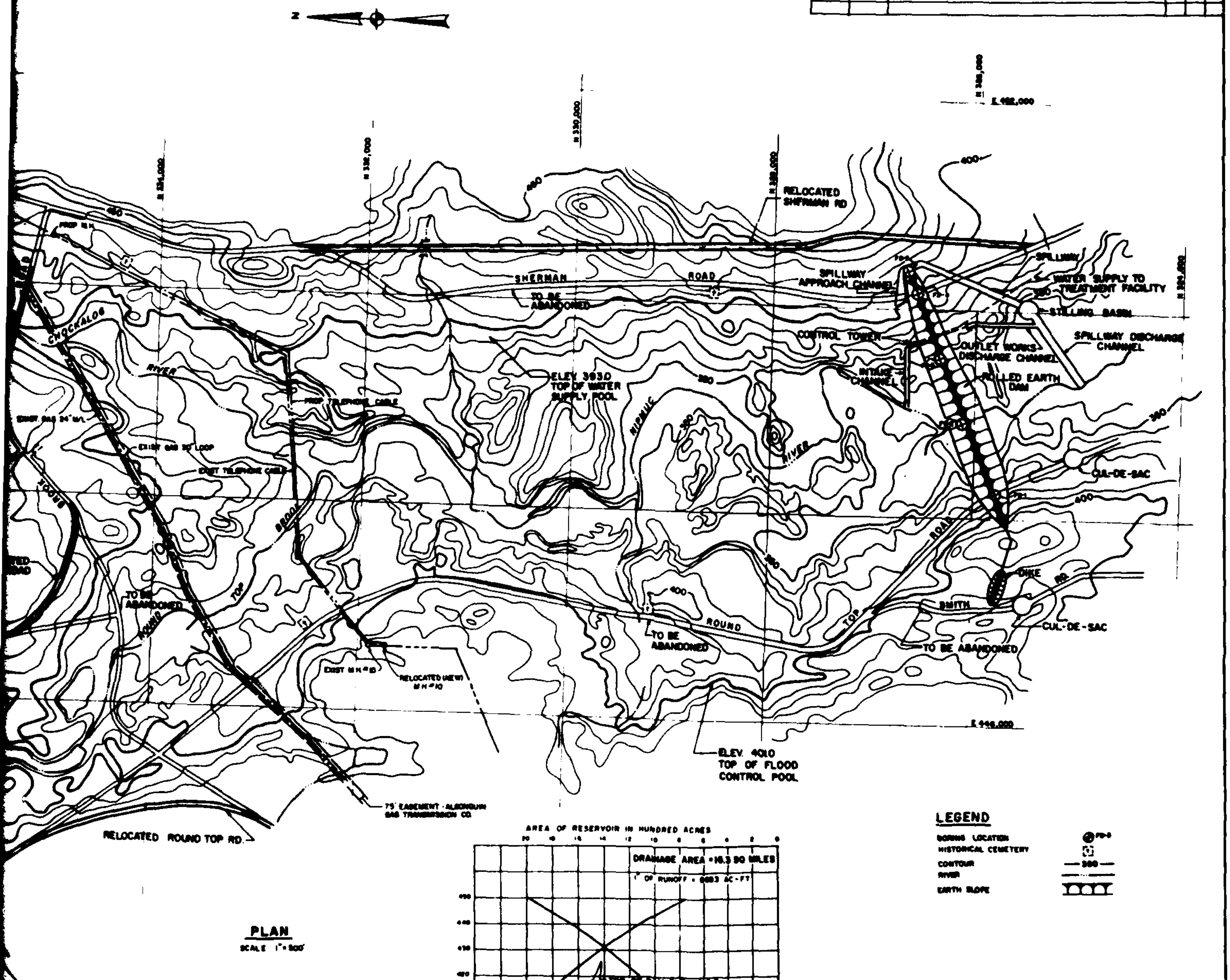
JUNE 1966

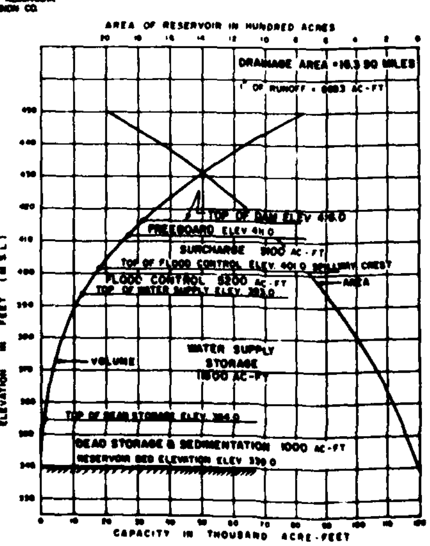
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE 55

2


LOCATION MAP
MASSACHUSETTS
RHODE ISLAND
ATLANTIC
OCEAN
TYPICAL EMBANKMENT SECTION
UPSTREAM
DOWNSTREAM
30'-0"
20'-0"
12'-0"
10'-0"
5'-0"
2.5
Impervious Core
Pervious
Random Pervious
Filter Material
Existing Grade
Toe Drain
Riprap
6" Loam & Seed
Top of Dam El. 416
NOTE
PLAN
GRAPHIC SCALES
EXIST GAS VALVE NO 36-2
TOWER 67
TOWER 66
TOWER 65
TOWER 64
E 462,000
E 460,000
E 448,000
E 446,000
E 444,000
N 336,000
N 338,000
N 340,000
RAISE BROOK ROAD
RELOCATED BROOK ROAD
CHOCKALOG RIVER
TO BE ABANDONED
COLLINS TAFT ROAD
UTILITY ACCESS ROAD
RELOCATED ROUND TOP RD.
ROUND TOP ROAD
BROOK
EXISTING R.O.W. BLACKSTONE VALLEY ELECTRIC CO.





AREA-CAPACITY CURVES

CE MAGUIRE, INC
ARCHITECTS ENGINEERS PLANNERS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

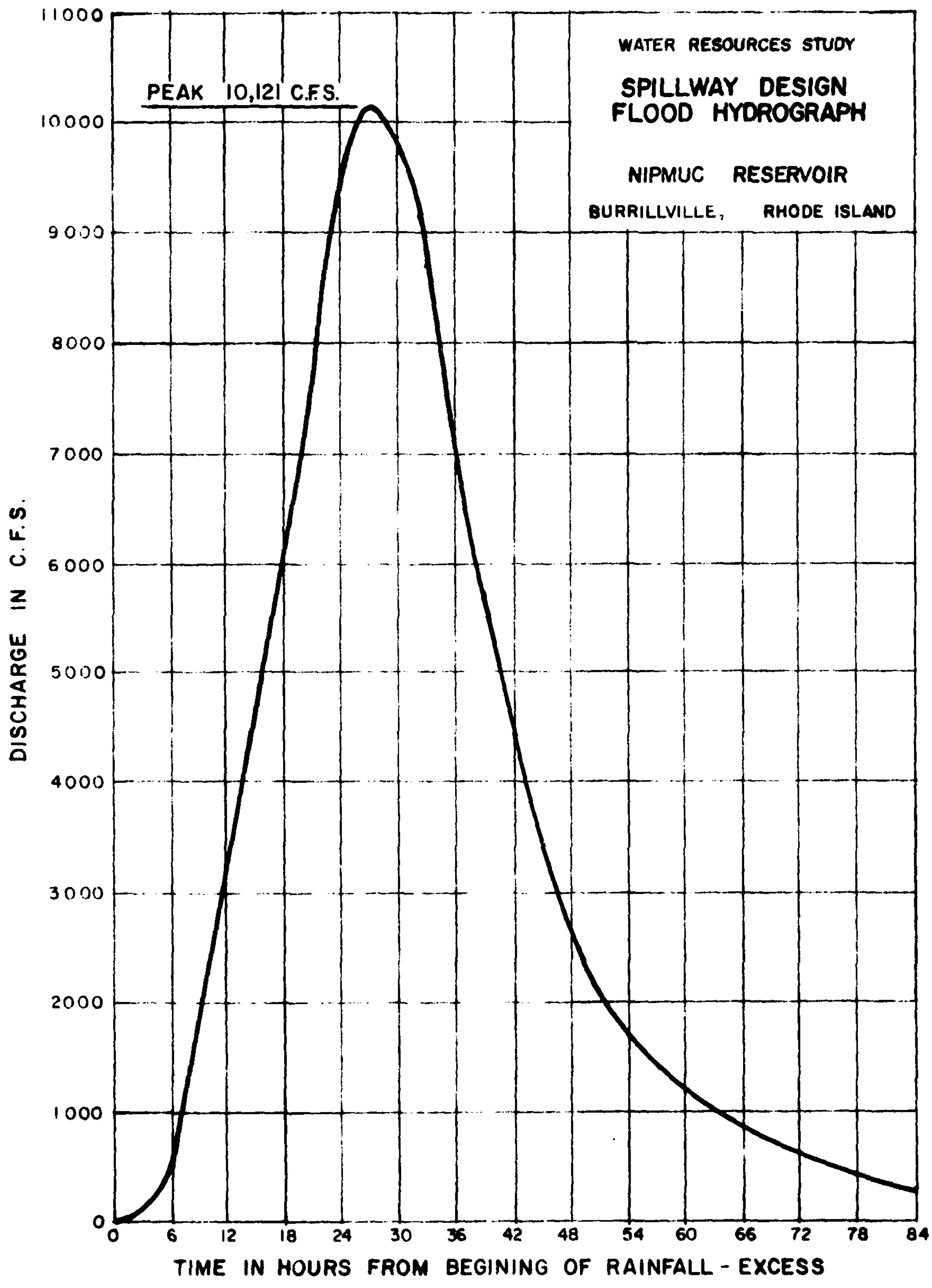
WATER RESOURCES STUDY

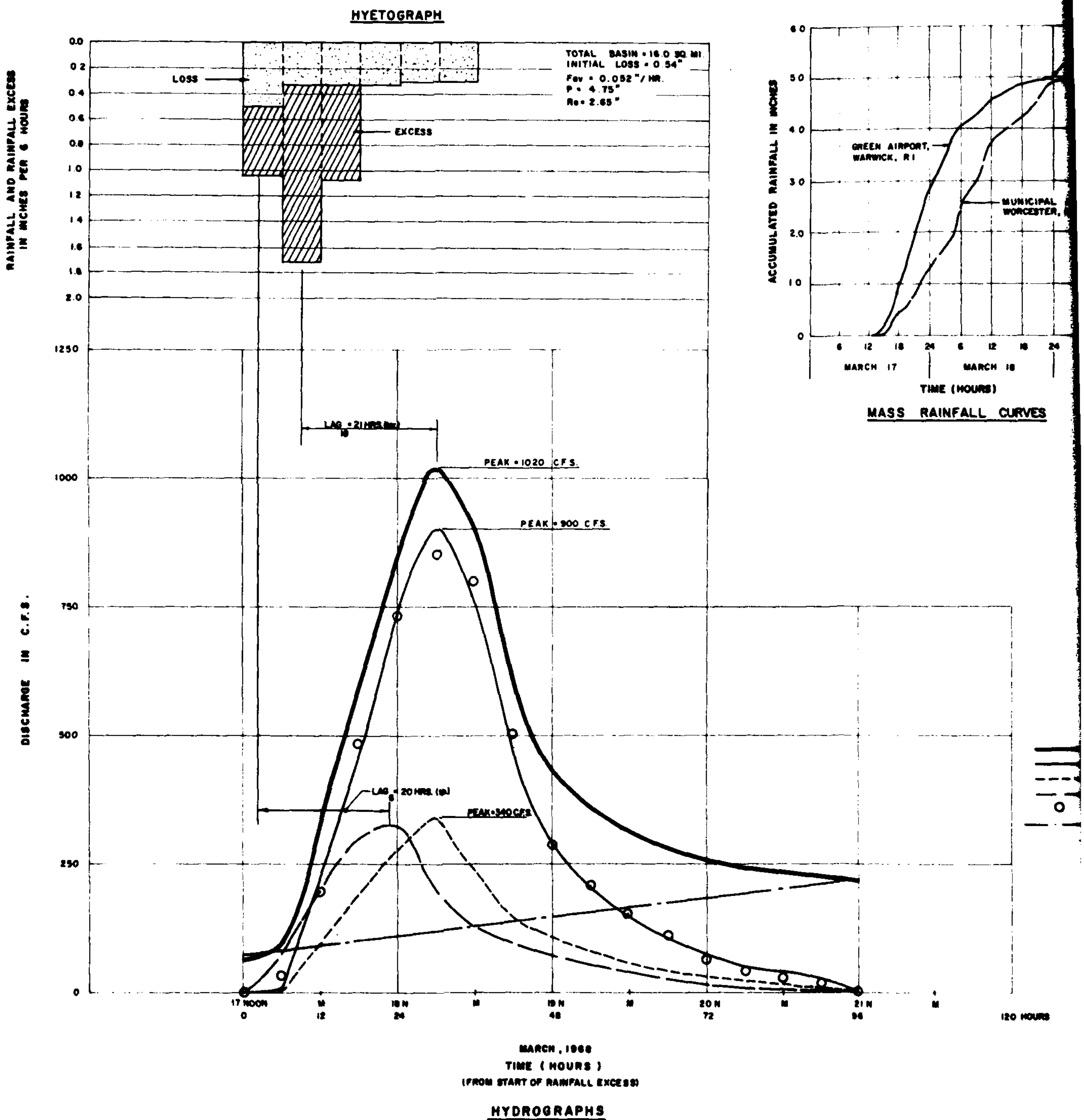
NIPMUC RESERVOIR

GENERAL PLAN

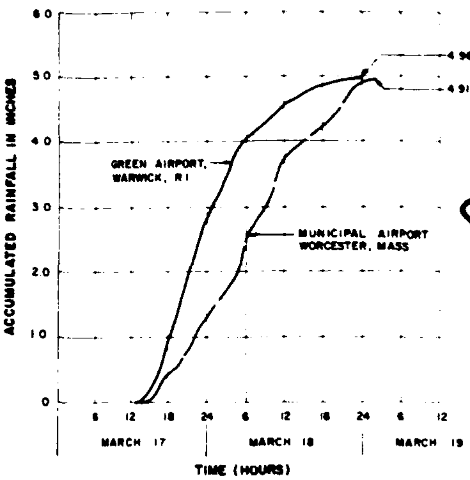
NIPMUC RIVER — BURRILLVILLE, RHODE ISLAND

PLATE 56

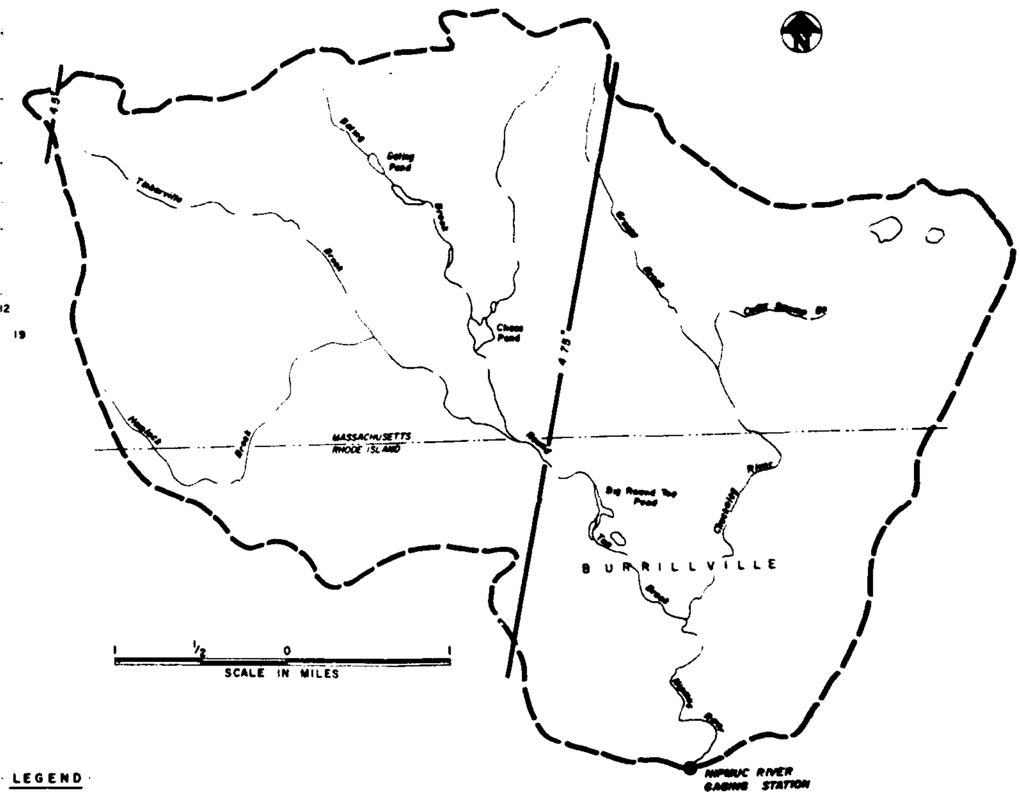

WATER RESOURCES STUDY
SPILLWAY DESIGN
FLOOD HYDROGRAPH
NIPMUC RESERVOIR
BURRILLVILLE, RHODE ISLAND
PEAK 10,121 C.F.S.
DISCHARGE IN C.F.S.
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
TIME IN HOURS FROM BEGINING OF RAINFALL - EXCESS

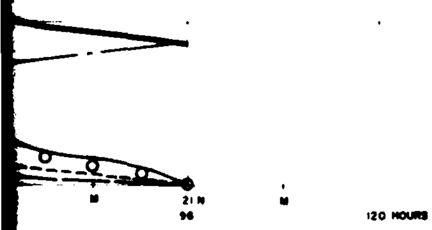

HYETOGRAPH
RAINFALL AND RAINFALL EXCESS IN INCHES PER 6 HOURS
LOSS
EXCESS
TOTAL BASIN = 16.0 SQ. MI.
INITIAL LOSS = 0.54"
Fav = 0.052"/HR.
P = 4.75"
Re = 2.65"
DISCHARGE IN C.F.S.
LAG = 21 HRS.
PEAK = 1020 C.F.S.
PEAK = 900 C.F.S.
LAG = 20 HRS.
PEAK = 340 C.F.S.
17 NOON
18 N
19 N
20 N
21 N
120 HOURS
MARCH, 1968
TIME (HOURS)
(FROM START OF RAINFALL EXCESS)
HYDROGRAPHS
ACCUMULATED RAINFALL IN INCHES
GREEN AIRPORT, WARWICK, R.I.
MUNICIPAL WORCESTER,
MARCH 17
MARCH 18
TIME (HOURS)
MASS RAINFALL CURVES

REVISION	DATE	DESCRIPTION	BY



MASS RAINFALL CURVES





LEGEND

- OBSERVED DISCHARGE
- SURFACE RUNOFF
- UNIT HYDROGRAPH (OBSERVED 18 HOURS)
- UNIT HYDROGRAPH (ADJUSTED 6 HOURS)
- O REPRODUCED HYDROGRAPH
- BASE FLOW

BASIN MAP

NOTE

PRECIPITATION STATIONS

GREEN AIRPORT, WARWICK, R I
MUNICIPAL AIRPORT, WORCESTER, MASS

C E MAGUIRE, INC.
ARCHITECTS ENGINEERS PLANNERS
PROVIDENCE, R.I. WALTHAM, MASS NEW BRITAIN, CONN

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

DES BY | DR BY | CK BY

SUBMITTED
CHIEF, HYD ENG SECTION
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, HYDR & WATER QUALITY BRANCH
APPROVAL RECOMMENDED
CHIEF, PLANNING & ENGRG DIVISION

WATER RESOURCES STUDY
UNIT HYDROGRAPHS
NIPMUC RIVER NEAR HARRISVILLE, R.I.
MARCH 17-19, 1968

APPROVED
CHIEF, ENGINEERING DIVISION
DATE

SCALE AS SHOWN | SPEC NO

DRAWING NUMBER

SHEET of

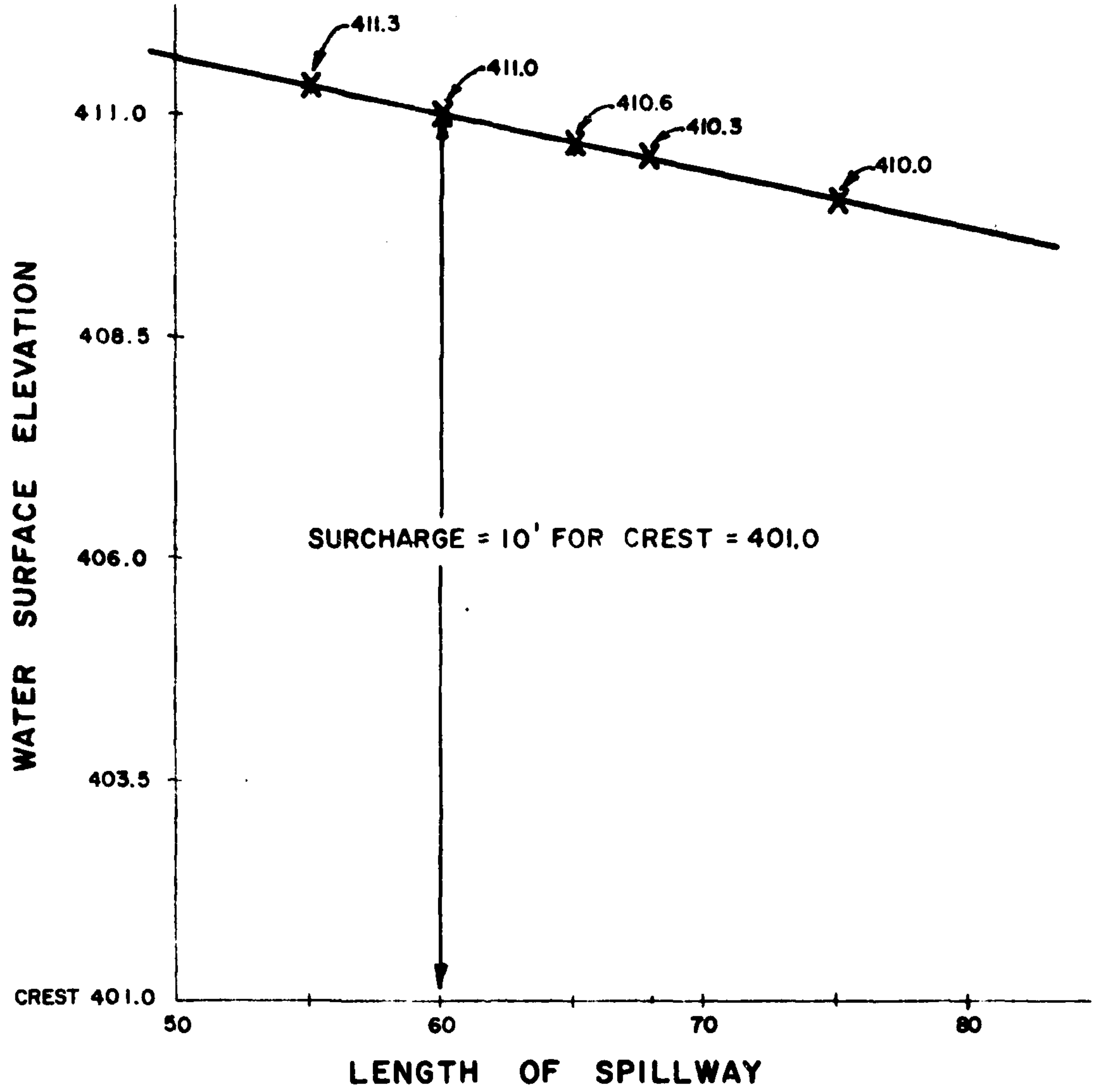
PLATE 58

2

NOTES :

ADOPTED LENGTH = 60.0'

SLOPE SURCHARGE LENGTH = 0.05'/ft.



SURCHARGE - LENGTH CURVE FOR SPILLWAY FLOOD AT NIPMUC RESERVOIR

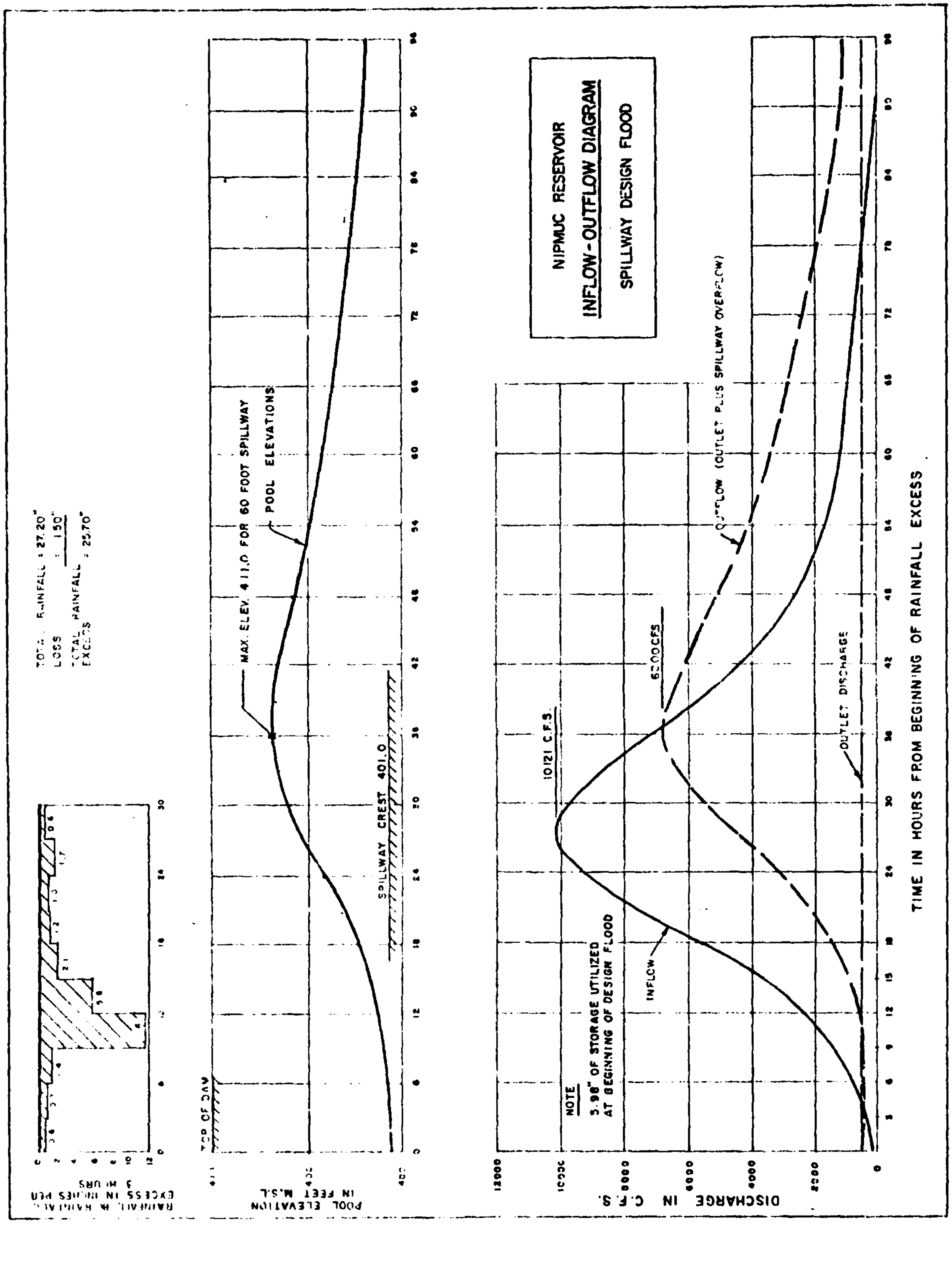
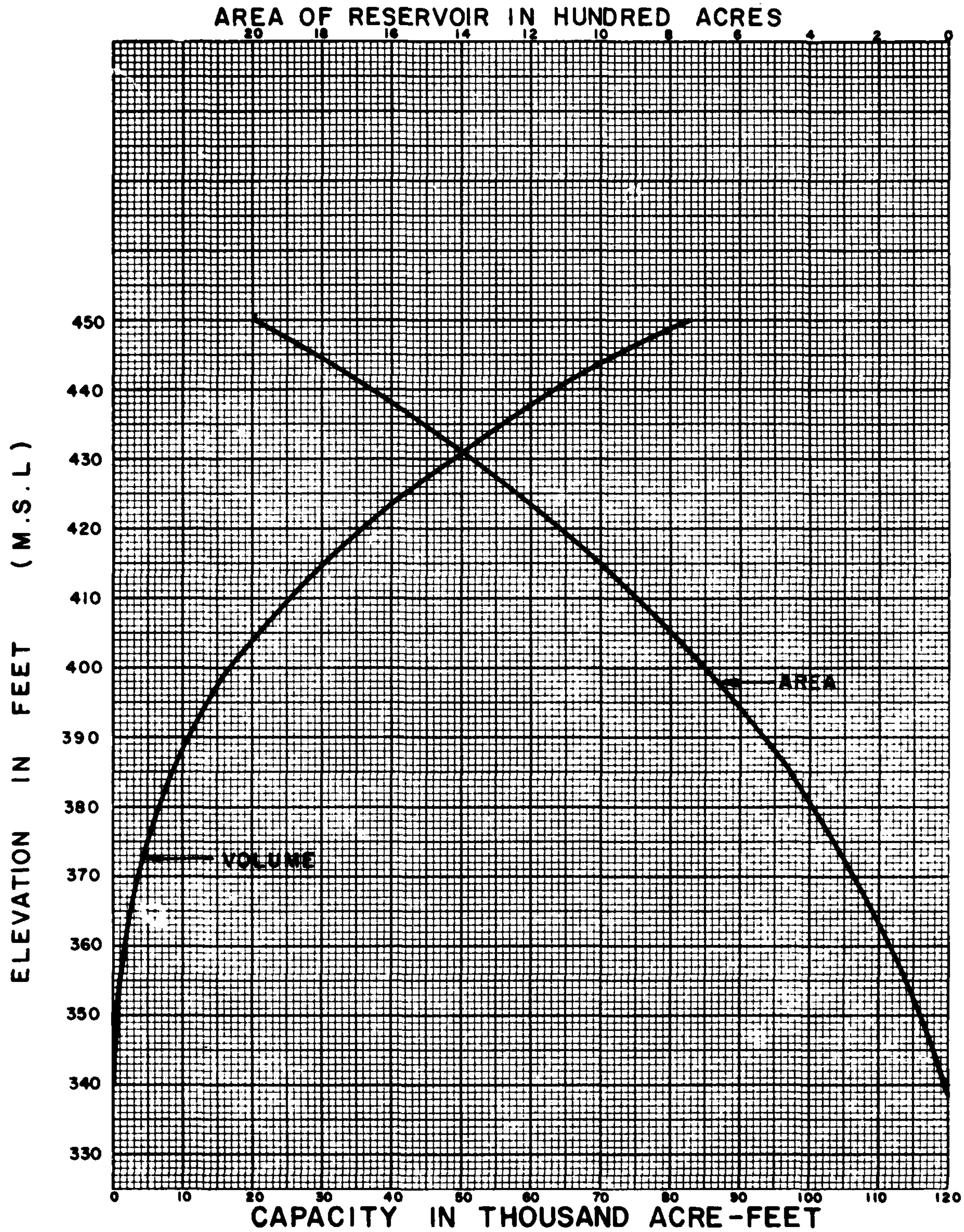
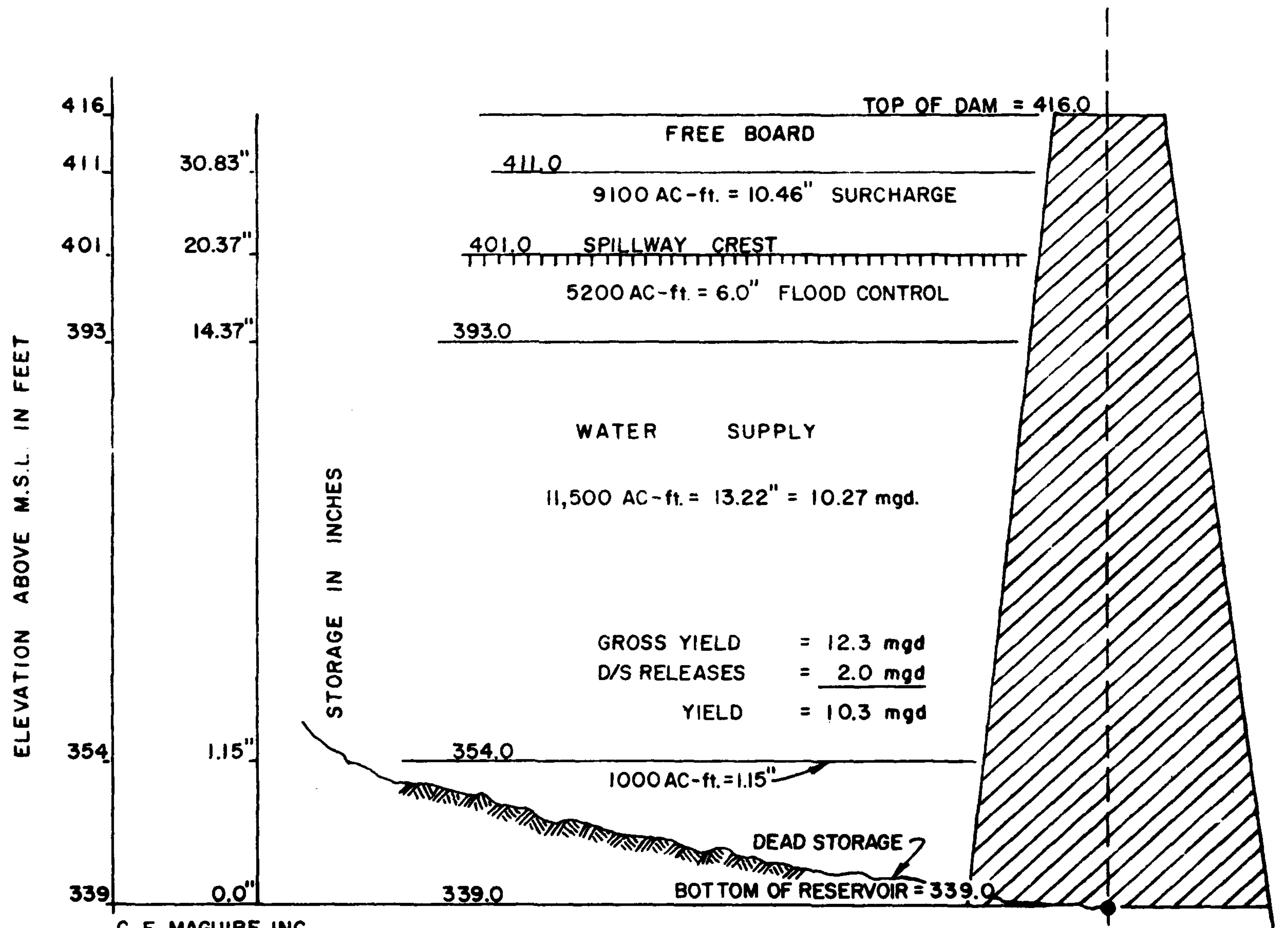

NIPMUC RESERVOIR
INFLOW-OUTFLOW DIAGRAM
SPILLWAY DESIGN FLOOD
TOTAL RAINFALL = 27.20"
LOSS = 1.50"
TOTAL RAINFALL EXCESS = 25.70"
RAINFALL IN RAINFALL EXCESS IN INCHES PER 3 HOURS
POOL ELEVATION IN FEET M.S.L.
TOP OF DAM
MAX. ELEV. 411.0 FOR 60 FOOT SPILLWAY
POOL ELEVATIONS
SPILLWAY CREST 401.0
DISCHARGE IN C.F.S.
10121 C.F.S.
6200CFS
INFLOW
OUTFLOW (OUTLET PLUS SPILLWAY OVERFLOW)
OUTLET DISCHARGE
NOTE
5.98" OF STORAGE UTILIZED AT BEGINNING OF DESIGN FLOOD
TIME IN HOURS FROM BEGINNING OF RAINFALL EXCESS
CE MAGUIRE, INC. WATER RESOURCES STUDY

PLATE 60

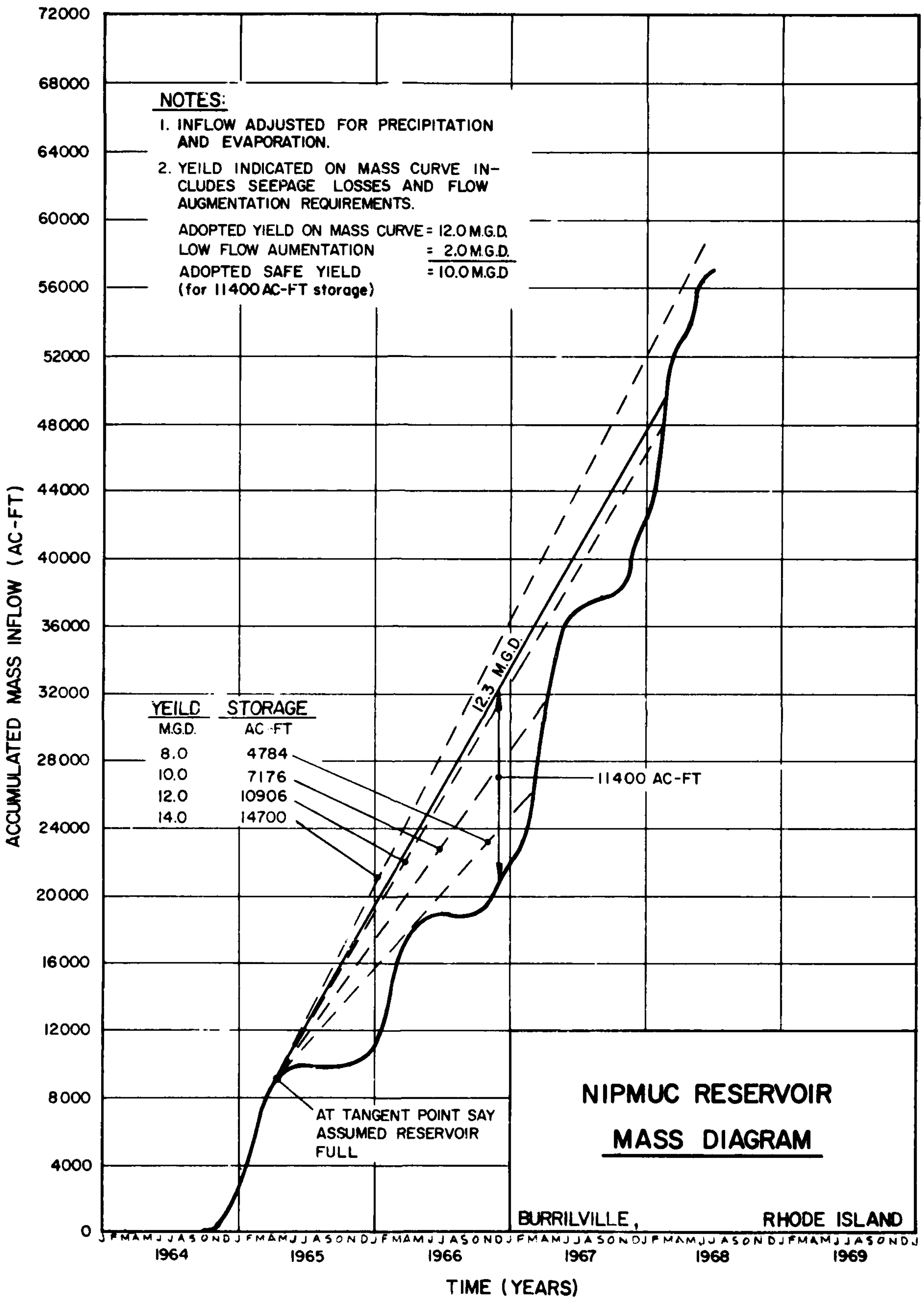


BLACKSTONE RIVER BASIN R.I.& MASS.	NIPMUC RESERVOIR
NIPMUC RIVER, R.I. & MASS.	DRAINAGE AREA 16.3 SQ.MI.
RIVER MILE 0.857	NAME: DATE: JULY, 1975
1" OF RUN-OFF= 869.3 ACRE(FEET)	C E MAGUIRE, INC. PLATE 61

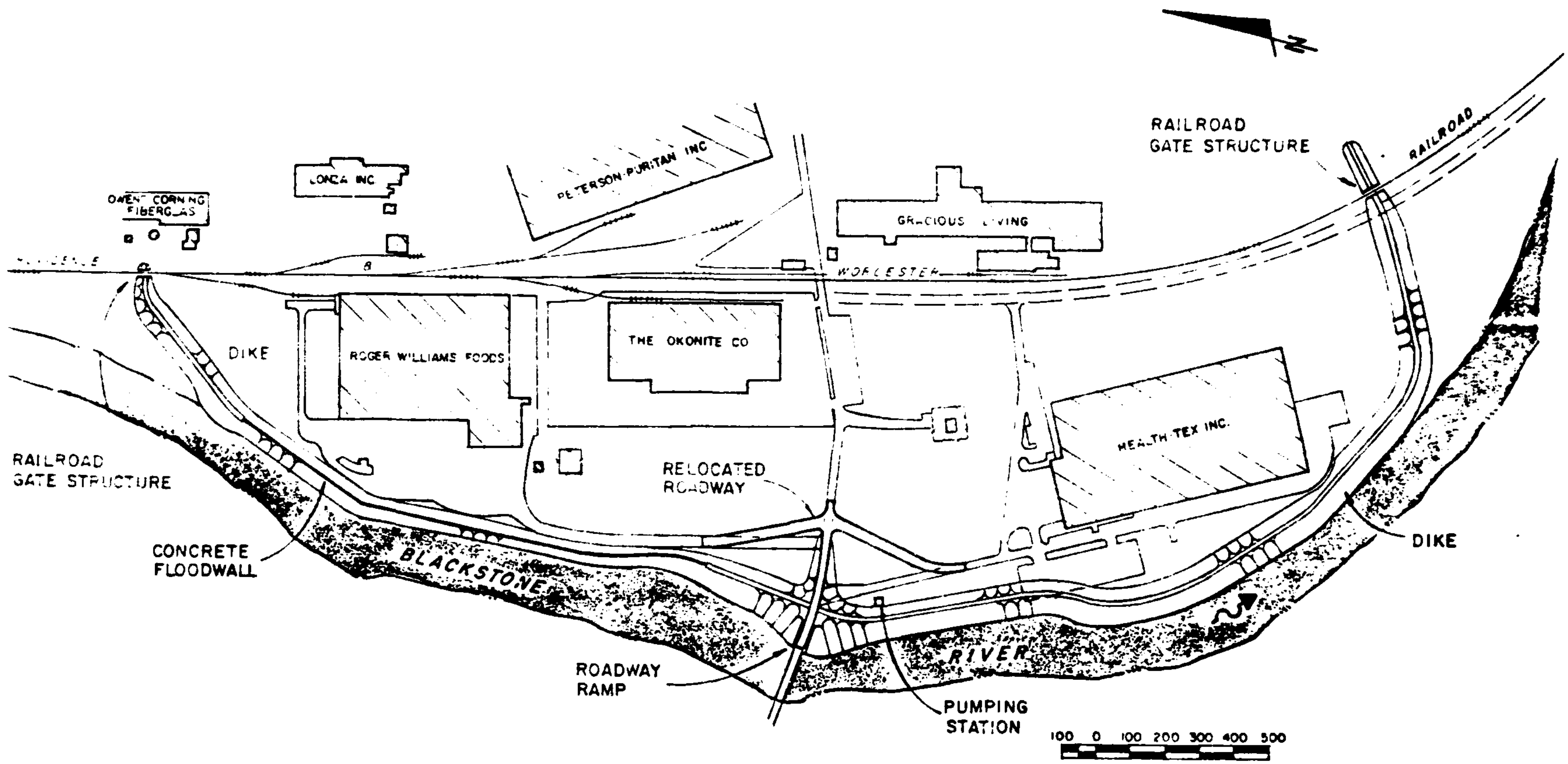
NIPMUC RESERVOIR STORAGE CAPACITIES



C E MAGUIRE, INC.
WATER RESOURCES STUDY



C E MAGUIRE, INC.
WATER RESOURCES STUDY



WATER RESOURCES STUDY

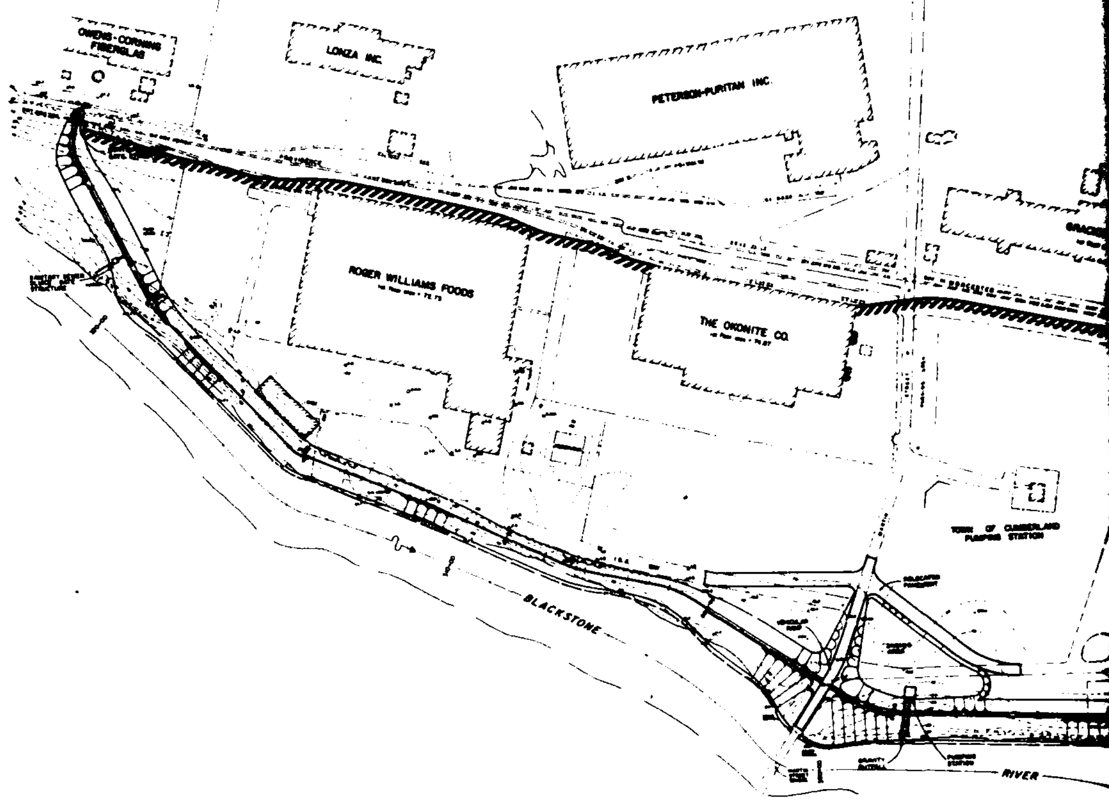
BERKELEY LOCAL PROTECTION PROJECT

CUMBERLAND, R.I.

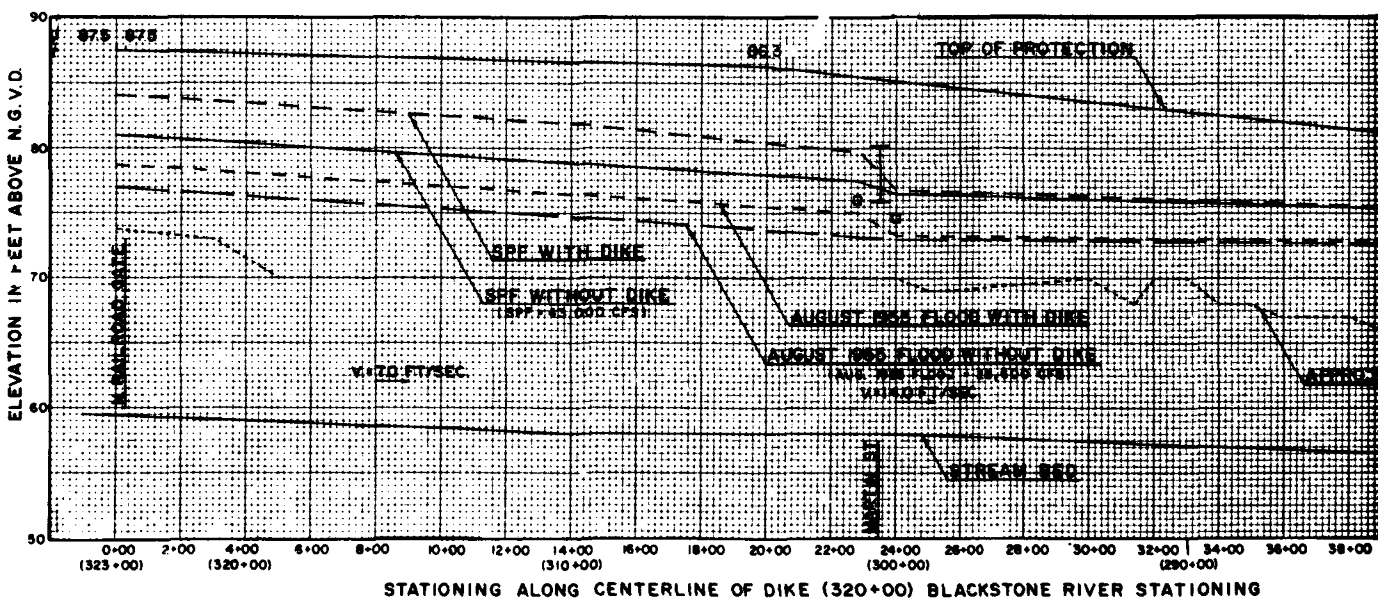
C E MAGUIRE, INC. DEC., 1975

PLATE 64

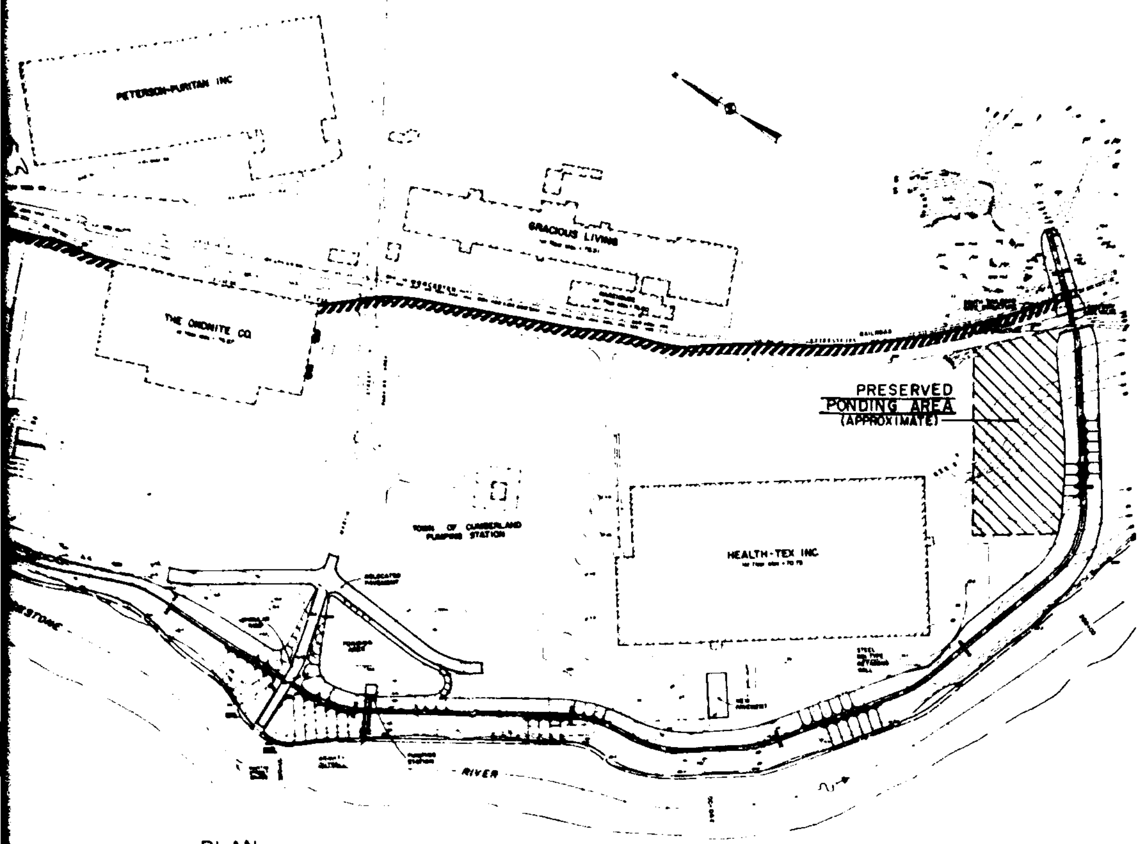
CORPS OF ENGINEERS



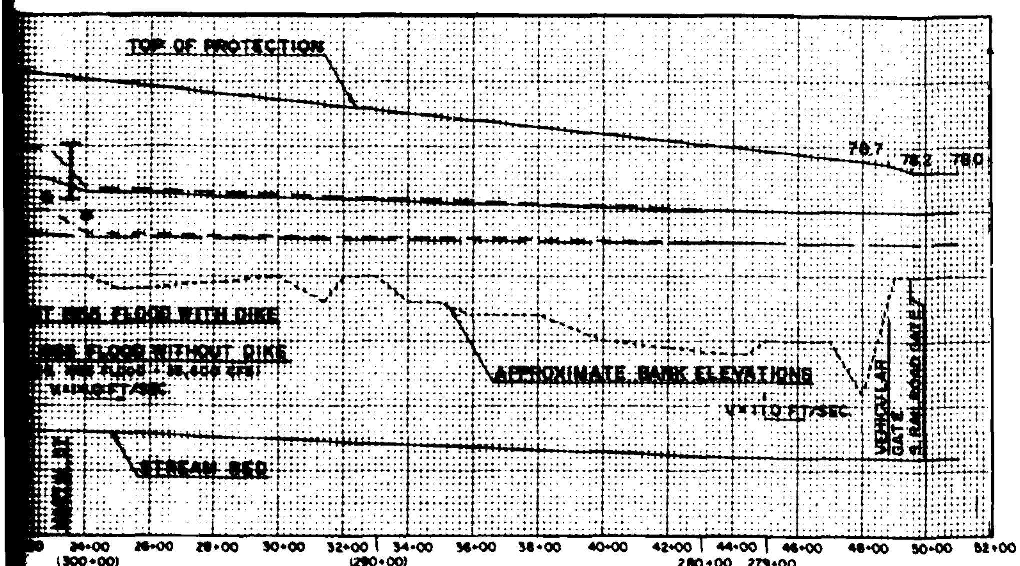
PLAN
SCALE: 1" = 150'



STATIONING ALONG CENTERLINE OF DIKE (320+00) BLACKSTONE RIVER STATIONING



PLAN
SCALE 1" = 150'



20+00) BLACKSTONE RIVER STATIONING

Experienced August 1955 Flooding

August 1955 High Water Mark

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

BLACKSTONE RIVER BASIN

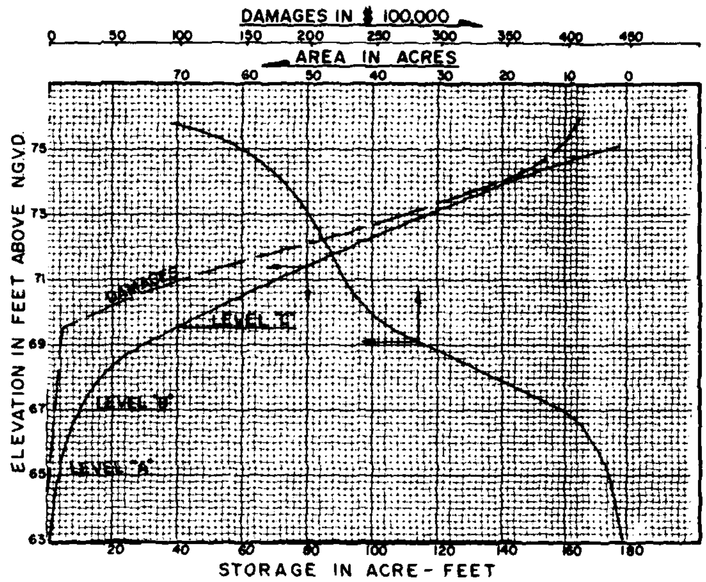
BERKELEY LOCAL PROTECTION

PLAN AND FLOOD PROFILE

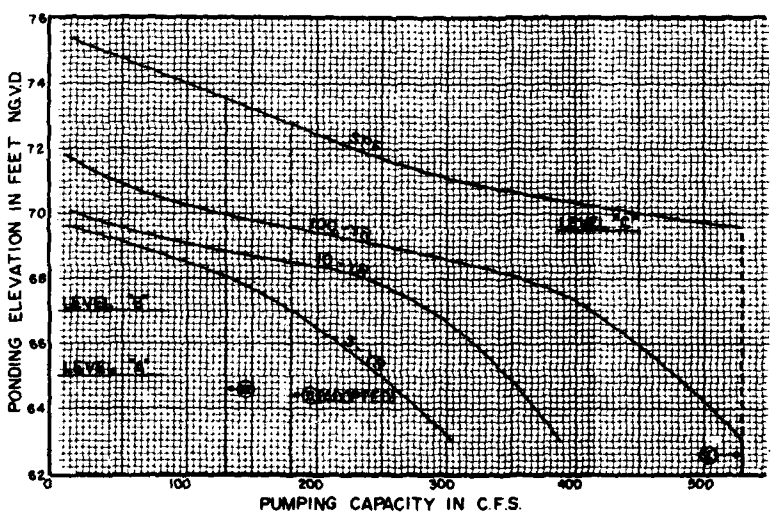
BERKELEY RHODE ISLAND

PLATE 65

2



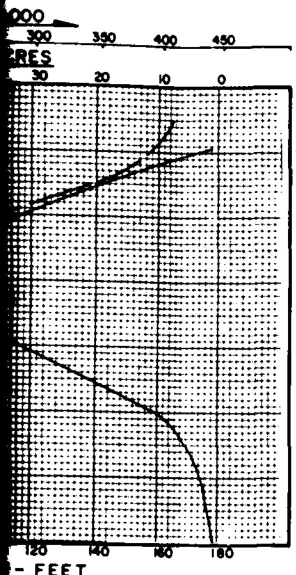
AREA - CAPACITY - DAMAGE CURVES



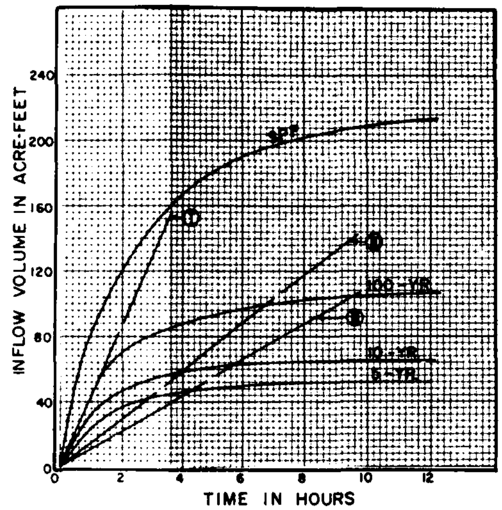
PONDING ELEVATION VS. PUMP CAPACITY

D E F G H

U. S. ARMY



AGE CURVES



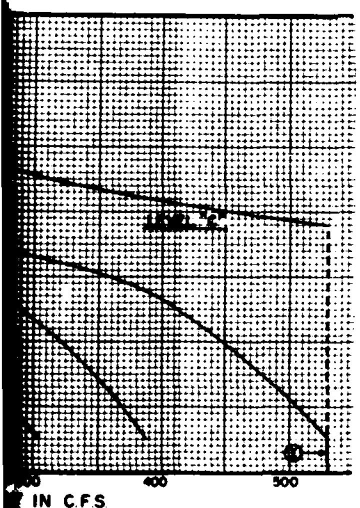
INFLOW VOLUME- DURATION CURVES

LEGEND

I - PUMP CAPACITY OF 530 CFS (100-YR. FREQUENCY STORM RUNOFF WITH NO INTERIOR PONDING)

II - ADOPTED PUMP CAPACITY OF 180 CFS (5-YR. FREQUENCY STORM RUNOFF WITH 10 ACRE-FEET PONDING)

III - PUMP CAPACITY OF 130 CFS (2-YR. FREQUENCY STORM RUNOFF WITH 10 ACRE-FEET PONDING)



PUMP CAPACITY

GRAPHIC SCALES

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

BLACKSTONE RIVER BASIN

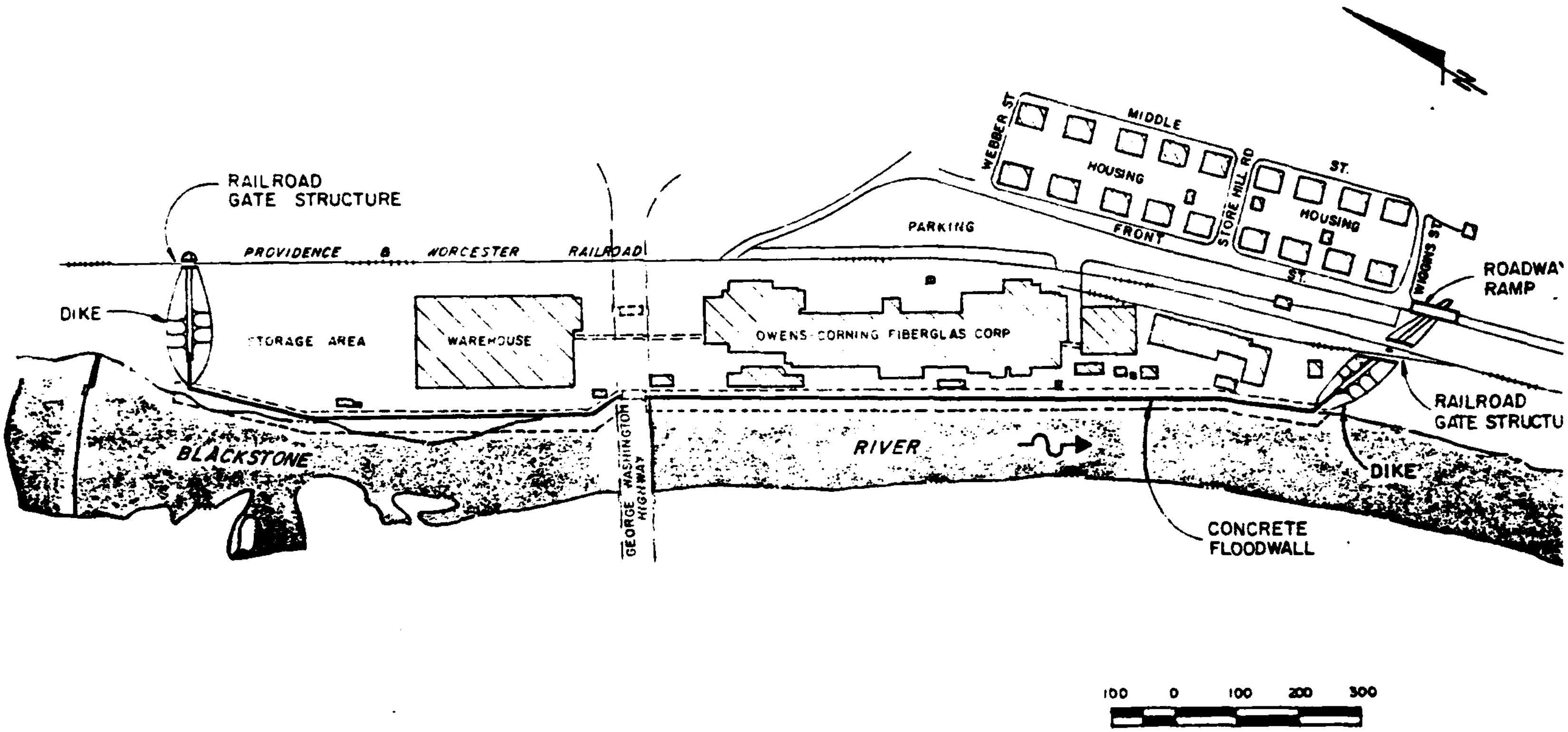
BERKELEY LOCAL PROTECTION

INTERIOR DRAINAGE HYDROLOGY

BERKELEY RHODE ISLAND

PLATE 66

1 2



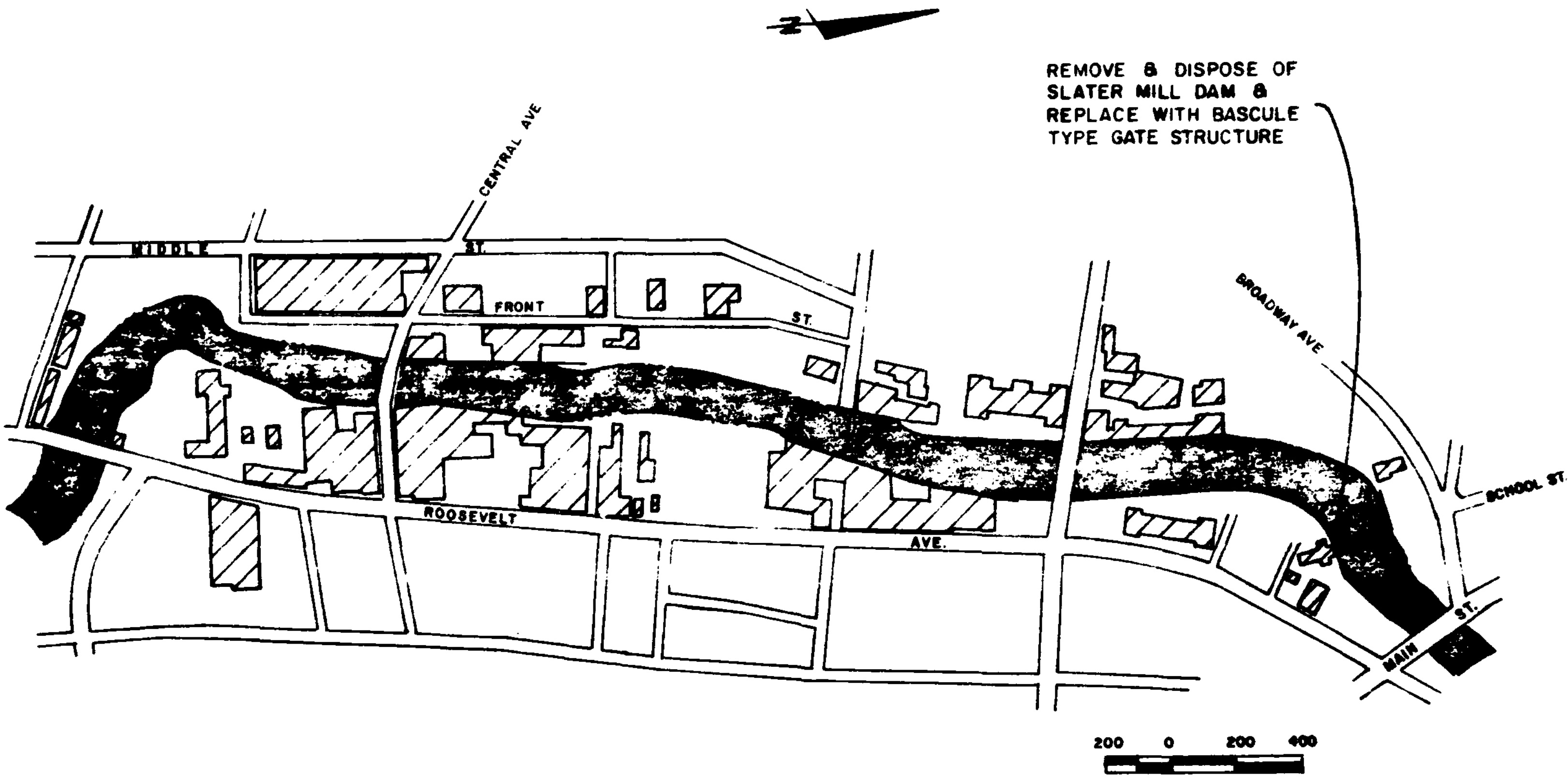
WATER RESOURCES STUDY

ASHTON LOCAL PROTECTION PROJECT

CUMBERLAND, R. I.

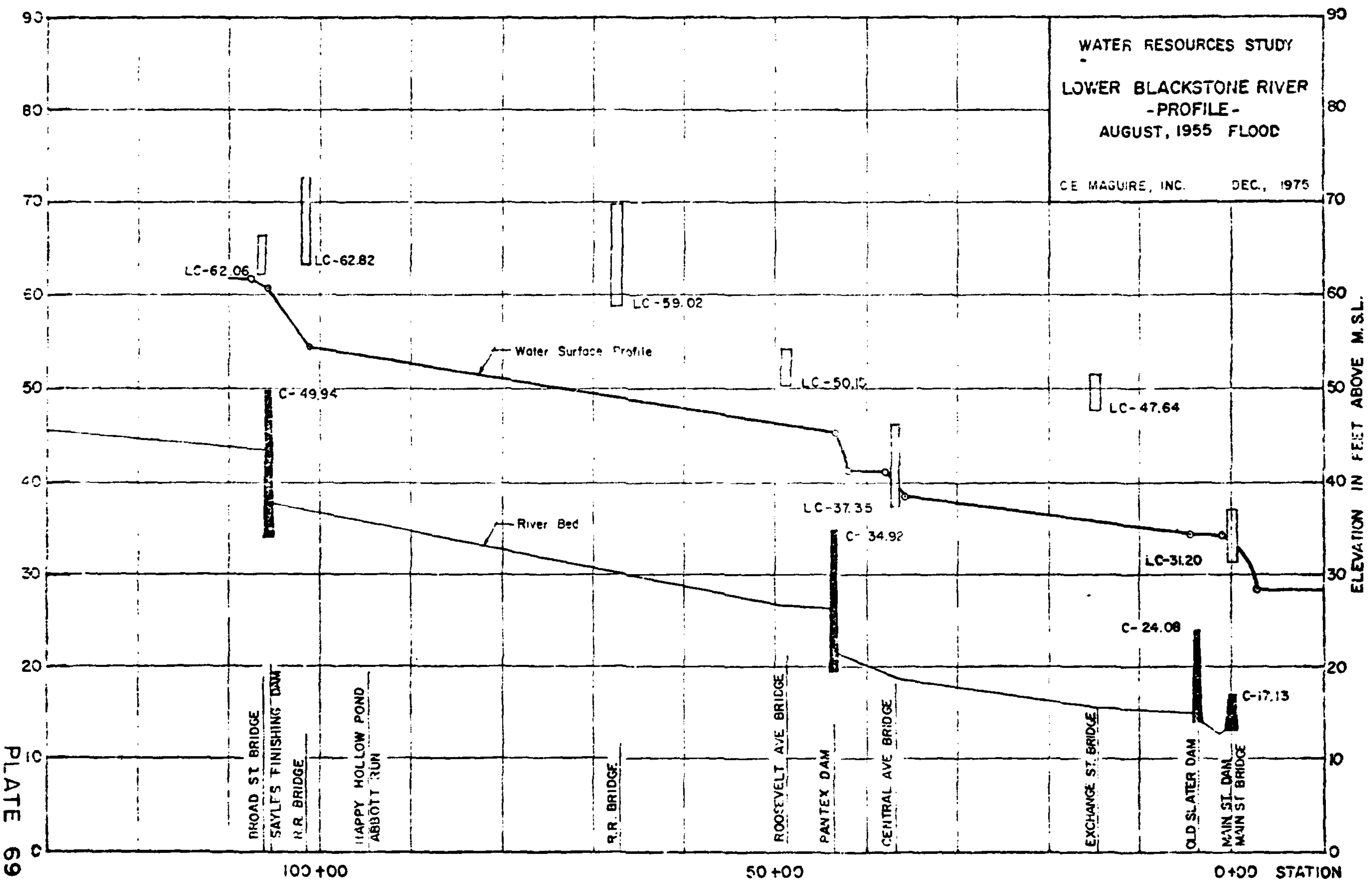
C E MAGUIRE, INC DEC., 1975

PLATE 67



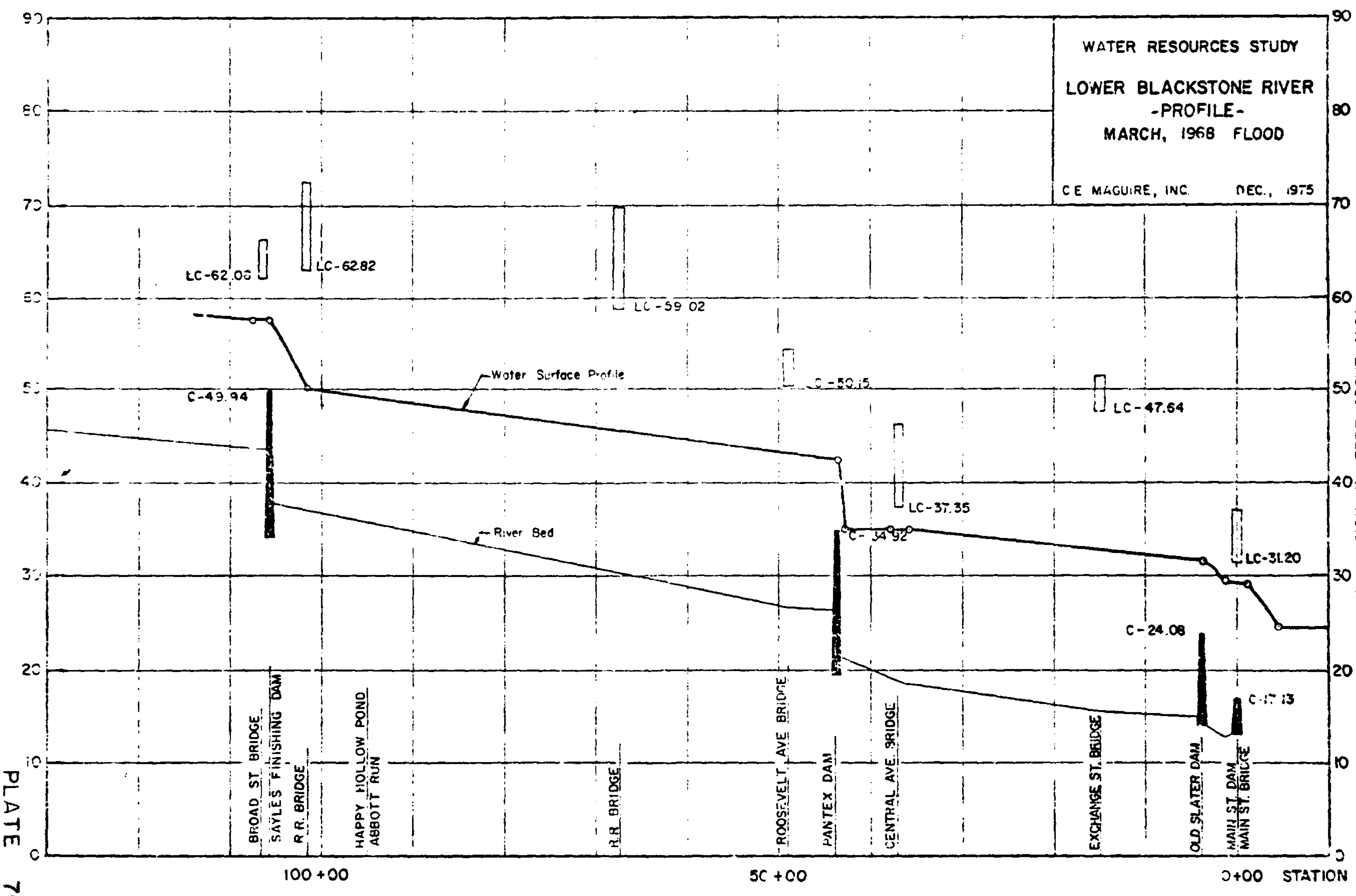
WATER RESOURCES STUDY
REPLACEMENT - OLD SLATER MILL DAM
PAWTUCKET, R.I.
C E MAGUIRE, INC. DEC., 1975

PLATE 68



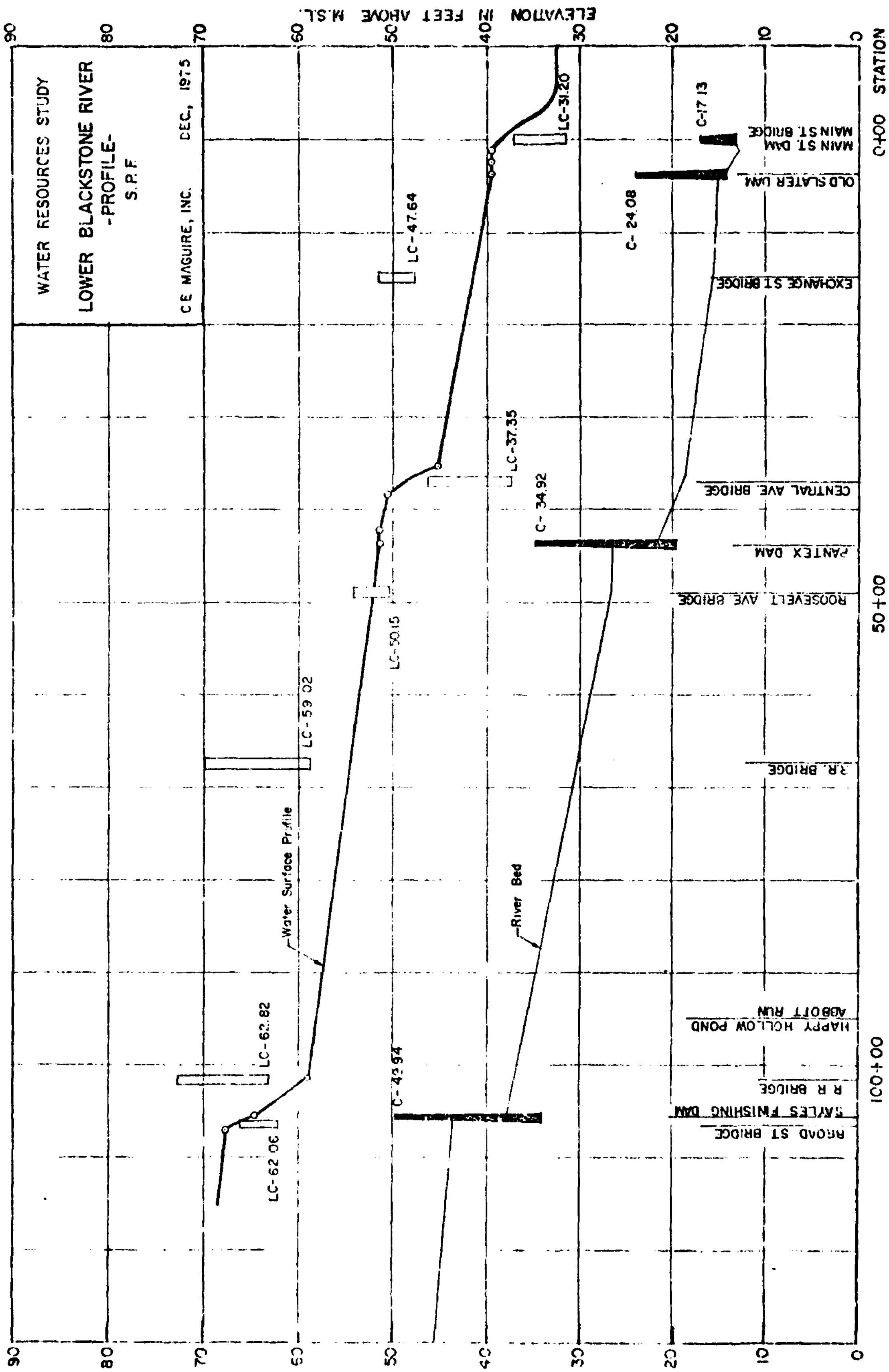
WATER RESOURCES STUDY
LOWER BLACKSTONE RIVER
-PROFILE-
AUGUST, 1955 FLOOD
CE MAGUIRE, INC.
DEC., 1975
ELEVATION IN FEET ABOVE M.S.L.
STATION
0+00
50+00
100+00
LC-62.06
LC-62.82
LC-59.02
LC-50.15
LC-47.64
LC-37.35
LC-31.20
C-49.94
C-34.92
C-24.08
C-17.13
Water Surface Profile
River Bed
BROAD ST. BRIDGE
SAYLES FINISHING DAM
R.R. BRIDGE
HAPPY HOLLOW POND
ABBOTT RUN
R.R. BRIDGE
ROOSEVELT AVE BRIDGE
PANTEX DAM
CENTRAL AVE BRIDGE
EXCHANGE ST. BRIDGE
OLD SLATER DAM
MAIN ST. DAM
MAIN ST BRIDGE

PLATE 69



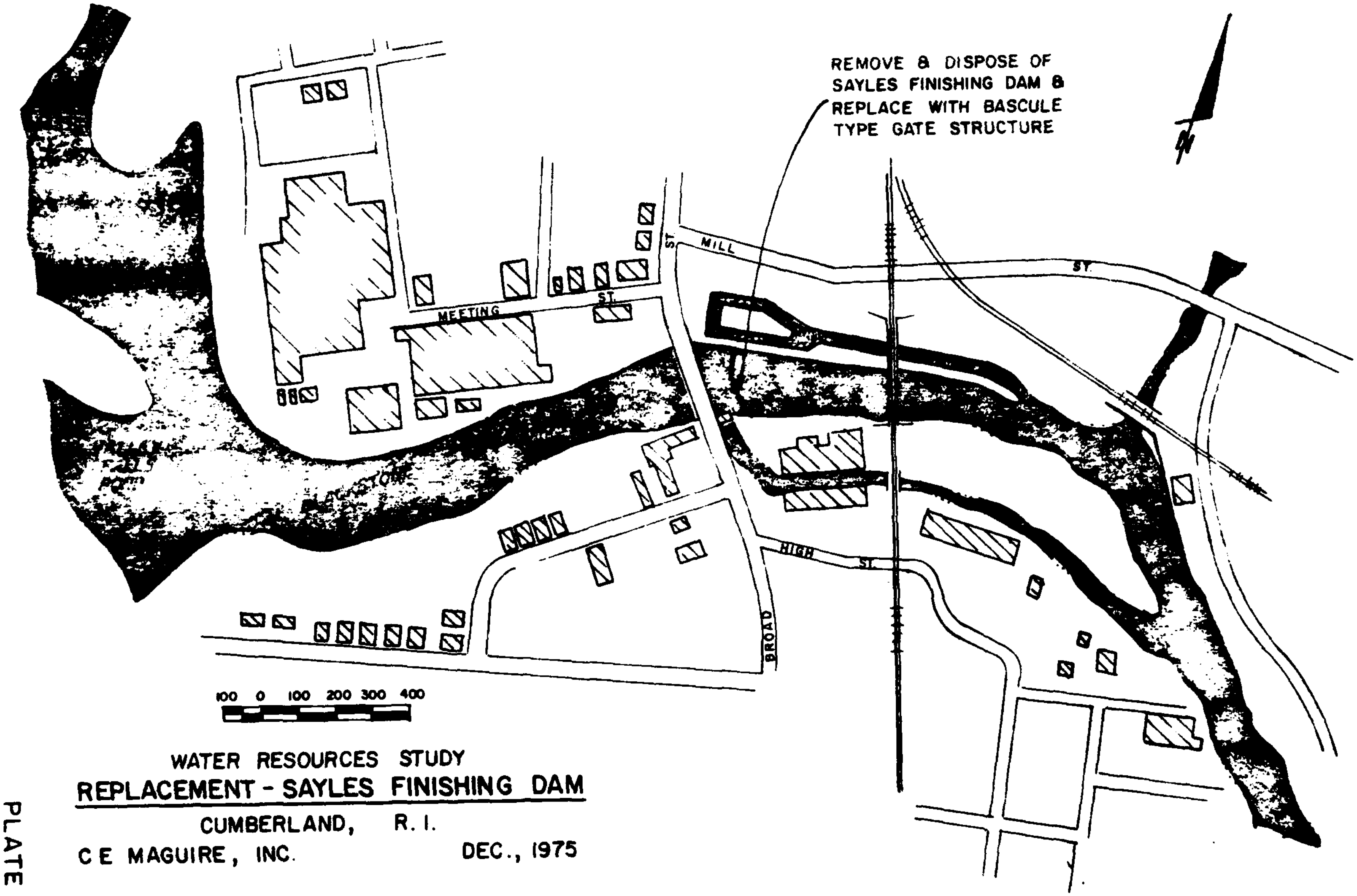
WATER RESOURCES STUDY
LOWER BLACKSTONE RIVER
-PROFILE-
MARCH, 1968 FLOOD
C E MAGUIRE, INC.
DEC., 1975
ELEVATION IN FEET ABOVE M.S.L.
STATION
0+00
50+00
100+00
Water Surface Profile
River Bed
LC-62.03
LC-62.82
LC-59.02
C-49.94
C-50.15
LC-47.64
LC-37.35
C-34.92
LC-31.20
C-24.08
C-17.13
BROAD ST BRIDGE
SAYLES FINISHING DAM
R.R. BRIDGE
HAPPY HOLLOW POND
ABBOTT RUN
R.R. BRIDGE
ROOSEVELT AVE BRIDGE
PANTEX DAM
CENTRAL AVE BRIDGE
EXCHANGE ST. BRIDGE
OLD SLATER DAM
MAIN ST. DAM
MAIN ST. BRIDGE

PLATE 70



WATER RESOURCES STUDY
LOWER BLACKSTONE RIVER
-PROFILE-
S.P.F.
C E MAGUIRE, INC.
DEC, 1975
ELEVATION IN FEET ABOVE M.S.L.
STATION
0+00
50+00
100+00
0
10
20
30
40
50
60
70
80
90
MAIN ST. BRIDGE
MAIN ST. DAM
OLD SLATER DAM
EXCHANGE ST BRIDGE
CENTRAL AVE. BRIDGE
PANTEX DAM
ROOSEVELT AVE BRIDGE
R.R. BRIDGE
ABBOTT RUN
HAPPY HOLLOW POND
R R BRIDGE
SAYLES FINISHING DAM
BROAD ST BRIDGE
LC-31.20
C-17.13
C-24.08
LC-47.64
LC-37.35
C-34.92
LC-50.15
LC-59.02
Water Surface Profile
River Bed
LC-62.82
C-42.94
LC-62.06

PLATE 71



WATER RESOURCES STUDY

REPLACEMENT - SAYLES FINISHING DAM

CUMBERLAND, R. I.

C E MAGUIRE, INC. DEC., 1975